The application of emerging new technologies by Portsmouth Dockyard 1790-1815

Thesis

UNRESTRICTED

THE APPLICATION

OF

EMERGING NEW TECHNOLOGIES

BY

PORTSMOUTH DOCKYARD

1790 - 1815

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ABSTRACT

The history of the Royal Navy during the war with France between 1793 and 1815 is well documented, but the part played by new technologies in maintaining the Royal Navy as an efficient fighting force and contributing to its ultimate success is much less well recognised. This thesis addresses this problem beginning with an examination of the demands made upon Portsmouth Dockyard, the largest of the Royal Dockyards, due to the growth in the size of the Fleet. It studies the nature of the tasks carried out in the Dockyard and the ways in which its personnel undertook them.

Following a review of emerging new technologies and considering those which were, or were not potentially relevant to the Dockyard's activities, the thesis examines the technological advances actually applied in the period, how they were related to the site, to each other and to the workforce. The main innovations resulted in a major increase in the throughput of the dry docks, due to new dock design and the imaginative use of steam-power. In the metalworking area too, steam-power, together with other new technologies, provided major benefits to the Navy as a whole, especially in the reprocessing of copper. In the woodworking area revolutionary new blockmaking machinery was at the forefront of advances in efficiency and increased output of blocks for the rigging of ships.

These advances were primarily due to a small group of men led by Samuel Bentham and Simon Goodrich, who became first "Engineer of the Navy". For their innovative use of new technologies and their management skills, these men can justifiably claim their place in the history of the Navy and of technology. More importantly, the applications of technology in Portsmouth Dockyard made a significant contribution to the industrial revolution in Britain during the period.

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CHAPTER ONE
BACKGROUND AND INTRODUCTION

1.1 Background. From the 1750s the pace of technological invention and change in Britain gathered such speed that by the turn of the century the country led the world in technological application and the output of its new factories was fundamental to the growth of the wealth which was vital to sustaining the struggle against Revolutionary France. In the war between 1793 and 1815, Britain depended on the Royal Navy to prevent an invasion of this country. Subsequently the British Army was totally reliant on its sister Service to protect and sustain the flow of men, ammunition and stores to the Duke of Wellington's forces in Portugal and Spain who provided the example to the rest of Europe and aided by British financial subsidies, eventually brought about the defeat of Napoleon's armies. In parallel with this the Royal Navy was central to the projection and protection of British trade around the world from PENANG in the East to BUENOS AIRES in the West. Without that trade, and the inflow of raw materials associated with it, the demand for the outflow from the factories would not have existed to the degree it did.

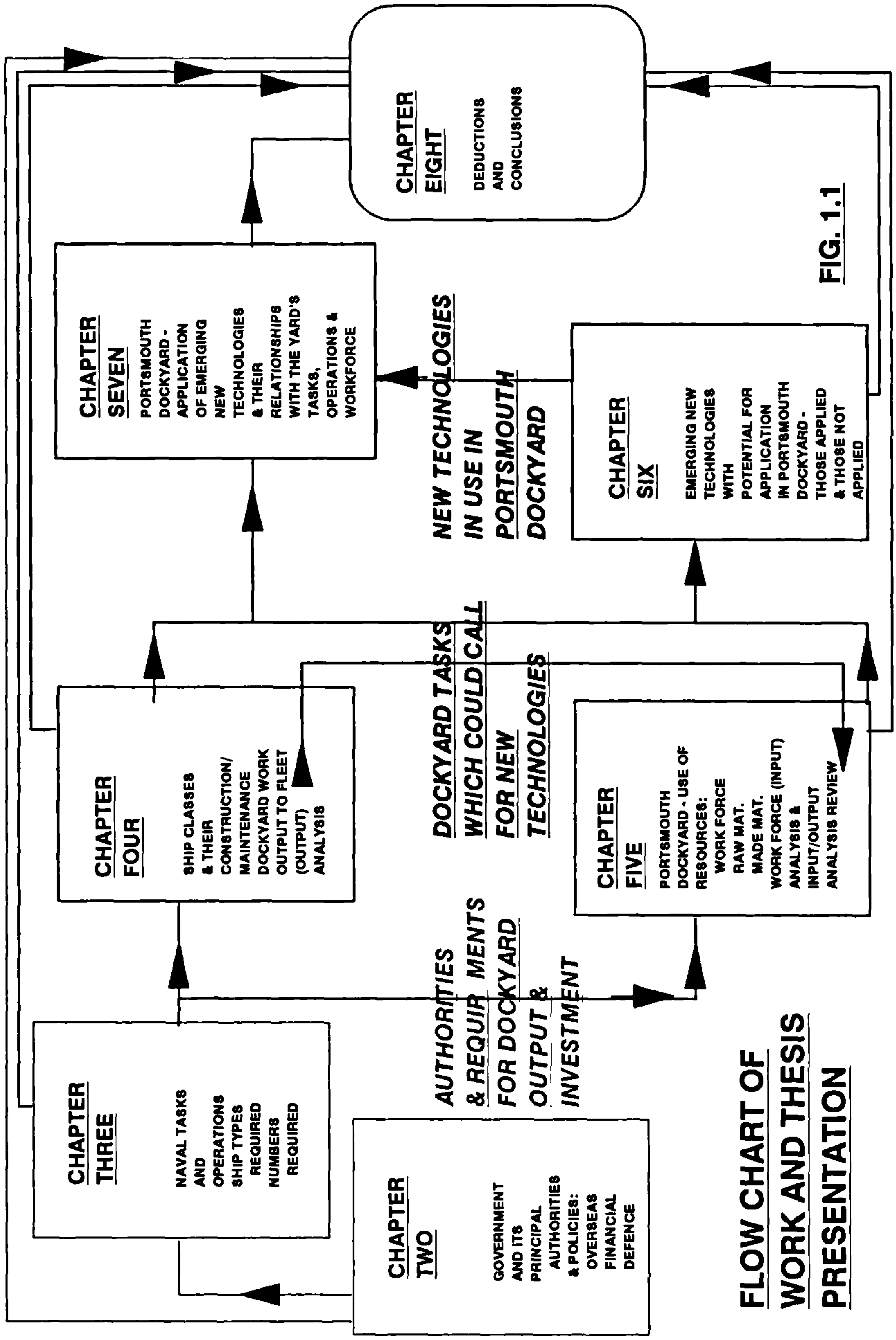
This dependence by Industrial Britain on its Navy is well documented but much less well documented is the Navy's dependence on support from within the country - other than perhaps the use of the 'Press' to provide manpower. The provision and maintenance of the Fleet at sea and transportation of the Army outside the United Kingdom would not have been possible without the pivotal role of the Royal Dockyards. It is a curious facet of the history of the Royal Navy down the ages that relatively little has been written about its support services and the tendency has been to denigrate the Dockyards for poor workmanship, corruption and general incompetence. Roger Morriss encapsulated this view when he wrote "Traditionally they (ie. the Royal Dockyards) have always been regarded as technologically backward compared with private industry, wasteful of public funds and ship-building resources and a check, from their inefficiency, on the efforts of the fighting navy"[1]. Whilst there is rarely smoke without fire it seems unreasonable that the Royal Dockyards are not given credit for keeping upwards of 600 wooden ships in a sea going state for over twenty years - that is no mean achievement at any time.

Portsmouth was the biggest of the six major Dockyards in terms of the number of ships it refitted. By 1813, it had a work force of over 4,000 (equivalent to 12,000 at today's population figures) and to the Dockyard numbers could be added those of the other support organisations in the area like the victualling and armament stores, let alone the sub contractors who supplied directly to the Yard. Within the boundaries of the Dockyard a whole range of crafts and skills were utilised and, as will be shown, a wide range of the emerging new technologies were being applied by the end of the war. Yet this Dockyard's standing in the history of the major industrial sites in this country at the start of the nineteenth century is barely recorded. This seems a loss to history particularly since on that one site new technologies were being applied in both the metal and wood areas as well as in a number of discrete "nautical" ones like docks and dredging.

1.2 Purpose. The purpose of this thesis is to demonstrate Portsmouth Dockyard's right to a place in the history of technical change and application around the end of the eighteenth/early nineteenth centuries.

1.3 Introduction. For the readers who will have to decide whether this case has been successfully established, this chapter sets out the rationale of the thesis and the order in which the evidence has been collected, assembled and assessed. The thesis starts by examining why the Government approved and funded in all but two years (1802 and 1803), an annual growth in the Navy from 1793 to 1813. It then moves to consider what this growth consisted of in terms of ship numbers and types and the resultant demand on Portsmouth Dockyard. This evaluation provided the essential basis for considering which of the emerging new technologies had potential for application in that Yard. In turn this led to the examination of those which were introduced and how they were brought together on one site and in relation to each other and the workforce. Figure 1.1 attempts to encapsulate the flow of the thesis graphically whilst the remainder of this chapter sets out each step in sufficient detail to provide an overview of the document as a whole. Throughout the document the spelling and punctuation of quotations are as they appeared in the original sources; weights and measurements are in imperial units, and prices in pounds, shillings and pence.

1.3.1. The Period 1790 - 1815: The period covered by the thesis runs from 1790 to 1815 within which the pace of technological change in the Dockyard accelerated because the Government and the influential trade bodies of the City of London clearly appreciated that the safety of the country and its overseas possessions from invasion or acquisition by the French depended on the Royal Navy. The war having created a climate in which change could take place, the costs and inevitable upheaval to the Dockyard were considered an acceptable part of ensuring the maintenance of the Fleet. However there was a short interval of peace in 1802-1803 during which the demand for output by the Dockyard was minimal and this affected the pattern of Dockyard work but not the installation of technology. With the end of the war the pace of change reduced dramatically and it was to be thirty years before there were significant increases



FLOW CHART OF WORK AND THESIS PRESENTATION

FIG. 1.1

in the level of demands on the Dockyard again. These were mainly brought about by developments in ship design and construction such as steam powered engines[2] and Pettit Smith's screw propeller[3]. Thereafter it was not until the start of the next century, with the introduction of the DREADNOUGHT class of battleships, that Portsmouth Dockyard regained some of its standing as a leading industrial complex.

1.3.2. Politics, The Government and the Higher level Naval Administration (Chapter 2): It is often forgotten by those serving within the Armed Services that the paying customer is the Nation and not the Services' own top management. The Nation, in the form of the Government of the day, tends to invest in the Armed Services out of fear of invasion, military disaster or loss of international standing. When these fears are not pressing any Government looks to see how small it can make its investment in the Services and thus how it can reduce its taxation demands on the voting public whilst keeping the support of a range of influential bodies - like the financial organisations in the City of London. Thus the starting point for considering Portsmouth Dockyard's technological record in the period has to be the Government of the day and what its demands on the Management of the Royal Navy were.

The top management of the two Armed Services received their funding primarily in relation to the tasks that the Government required them to undertake and in making their case for financial resources those managements had to justify, in specific detail, major capital expenditure on new units or, in the case of the Admiralty Board (on behalf of the Royal Navy), on the new build/re-build of ships. The detailed management of the support arrangements for the running fleet was delegated by the Admiralty Board to subordinate bodies who in turn tasked and financed the individual organisations and sites such as the Dockyards. Thus those yards served three masters; their immediate organisation's Headquarters (The Navy Board), the Admiralty and the Government. Additionally they had to respond to, and take advantage of, the various "advisers" their superiors employed and it needs to be borne in mind that at this time in history "patronage" was an acceptable, indeed desirable, part of the structure of "power" within the nation. As will become clear, the Nation, the Royal Navy and Portsmouth Dockyard were extremely fortunate to have available such gifted men as Samuel Bentham and Mark Brunel, to mention but two, who collectively formed the "engine of innovation" for introducing technological advances in Portsmouth.

The Navy's administrative process was investigated in some depth by Roger Morriss whose findings are recorded in his book *The Royal Dockyards during the Revolutionary and Napoleonic Wars*[4]. As that work shows the administration of the Royal Dockyards is a subject in its own right and whilst it is not possible in this thesis to avoid it, discussion on it is limited to the detail needed to support the main thrust of establishing Portsmouth Dockyard's standing in the history of technology.

1.3.3. The Naval Requirement - Fleet operations and composition (Chapter 3). The broad Governmental strategic demands of protection from invasion, protection and projection of trade and support to the Army translated, in the maritime environment, into a number of different types of operations each of which called for a mix of ship types. The net result was a major change in the size of the fleet and its composition as the war progressed.

The Royal Navy started the war in 1793 with 390 ships and this number grew until by 1808 it was over 900. It is entirely reasonable to assume that the demand for increases in output from Portsmouth, in percentage terms, would not have been less than the percentage increases in the size of the fleet since there was an obvious, and direct link with increases in ship numbers and increases in the work to maintain them in a sea going state. Therefore the annual increase in the size of the fleet can be regarded as the "Requirement" for a corresponding increase in Portsmouth's output. When the fleet increase rate was higher than that of the Dockyard it is fair to assume that the Dockyard then came under very considerable pressure to increase output and try and catch up with the "Requirement".

One way that the Dockyard was able to increase output, in the very short term, was to sacrifice any new build or re-build work aimed at sustaining fleet numbers in the long term and concentrate all its efforts on just getting ships back out to sea. However "short termism" of this type resulted in even greater demands on the Dockyard in later years as the consequences of "robbing Peter to pay Paul" caught up. Later in this document the rate of change in the Requirement, representative Dockyard outputs and representative Dockyard inputs are all compared to assess both the pressure, and the incentive, operating on the Dockyard to introduce new technology and mechanical innovation.

1.3.4. The Fleet - Maintenance of its ships by Portsmouth Dockyard (Chapter 4): It is a statement of the obvious that the near totality of Portsmouth Dockyard's output derived from work on the ships that entered it and hence it is necessary to have some understanding of those ship types.

The Fleet was composed of a variety of classes of ships the biggest of which were ships like HMS VICTORY who had a crew of 850 men[5], carried over a hundred heavy guns and could, without any assistance from external sources sail to the West Indies and back - in ideal wind conditions a ship of this class could travel 200 miles, or more, in a day. At this time in history these ships could lay claim to being the most sophisticated machines built by man and the fact that many remained in operational service for as much as 30 years, or more, is an undoubted tribute to their maintainers as well as to their crews. At the lower end of the scale there were a range of small craft which were no match at all for the bigger vessels in terms of military might but were very much their equals in terms of the time they spent at sea and the adverse wind and sea conditions they endured. Not surprisingly, continuous service for these vessels called for considerable refitting effort.

Whilst the size and scale of the different ship types altered, the basics of their construction were very much the same and of course it was elements of this construction that were replaced or restored when ships were refitted. For the purposes of considering the application of emerging new technologies this construction work can conveniently be examined under the headings of metal, fibre, wood and, inevitably miscellaneous work. This latter area embraces those elements which do not fit naturally under one of three more definitive headings.

The scale of the Dockyard's output can be represented in a number of ways. There is the obvious method of counting the number of ships sent out to re-join the operational fleet each year and this was probably the only output figure the sea going commanders were interested in. However the use of this figure is somewhat limited in trying to scale the dockyard work load since it takes account of neither the length of time a ship was worked on nor the size of the ship. These problems can be overcome by using the number of days a ship was in dry dock (over 80% of ships entering the Dockyard went through the dry docks) and ships' tonnages. From the one thousand, eight hundred and ten records of ships entering Portsmouth Dockyard between 1790 and 1815 it is possible not only to see what work was done on the individual ships but also to generate representative annual figures which reveal the year on year changes in Dockyard output. As was stated earlier those figures can immediately be compared with those for changes in the size of the Fleet to show how "output" was/was not lagging against demand and hence indicate a pressure on the Dockyard for even more output. They are also used in conjunction with "input" figures and this is discussed in a moment.

1.3.5. Portsmouth Dockyard's Resources. (Chapter 5): The range of resources which made up the total input to the Dockyard's work process was wide but by far the most significant was manpower since, with all tasks being manual, an examination of the skills and crafts employed across the work force leads naturally to the identification of individual processes carried out and with what tools. Thus the potential candidate areas for new technology are revealed but of course it is important to refer back to the detail of where the work was undertaken because what might be possible in a steam powered factory might not be possible in the bottom of a ship simply because there was no way of delivering steam power to such a site. Whilst it is not feasible to enumerate the year on year changes in material input to the Dockyard it is possible to do so in respect of the manpower and this allows for the direct pattern of change in the metal, fibre, wood and miscellaneous work forces to be enumerated. These changes are also taken as representative of the annual changes in resource utilisation as a whole.

Bringing together the results of the output analysis described earlier, with that of the input mentioned above provides the basis for a considered assessment, after making allowances for administrative improvements, of the benefit of the introduction of new technology in terms of more output for the same human input or the same output for a reduced human input. On this, in the first instance, depends the whole validity of Portsmouth's claim to a place in the history of technology since, without a financial profit to show for its investment in technology, productivity increases are the only solid grounds on which a claim for "success" in a technical investment can be made. Additionally this form of assessment can be of great help in arriving at a balanced judgement on which technological advances provided the most benefit since it does not follow that the most "glamorous" advances were the most significant. For example the replacement of human "mud shovellers" by a steam powered machine may not, at first sight, grip the imagination as a major technical advance but its effect was significant for the Dockyard.

1.3.6. Available Technology with potential for exploitation in Portsmouth Dockyard (Chapter 6): The sum of the work up to this point provides the solid basis for a review of the significant emerging technologies in terms of which ones had potential for application in Portsmouth Dockyard and which did not. Of course it is a matter of judgement which specific technical advances meet the criteria of "significant" and "potential" for inclusion in the list this work examines. The "significant" has been assessed relative to the on going work practices, examined in the earlier Chapters of the thesis. The claims for "potential" is discussed in this chapter. Inevitably, given the constraints of study time and resources, there will be some inclusions and some exclusions which can be challenged but it is believed that they would be very unlikely to change the conclusions of the outcome of the thesis as a whole.

By this point in the thesis the great majority of those which were applied have been identified and their technicalities are then examined, although the detail of their specific "on site" applications is discussed later on. However, for the Dockyard's case to be properly established it is also necessary to investigate why other, potentially applicable, technologies were <u>not</u> introduced.

The reasons why a particular technical advance, which is assessed as having potential for application in Portsmouth Dockyard was <u>not</u> pursued can often be multi-facetted. At the highest management level there could have been both overt and covert administrative inter actions between the Government, the Admiralty and the Navy Board and those are a subject for study in their own right and outside the scope of this thesis. For the purposes of this work attention to such matters is restricted to "decision points" directly affecting Portsmouth. Immediately superior to that dockyard was the Navy Board which was charged with the administration of the Dockyards as a whole and inevitably considerations of overall plans, priorities and global resource difficulties would have had a major bearing on its responses to proposals and requests from Portsmouth. Here again attention is constrained, outside the scope of technology, to "decision points".

Within Portsmouth Dockyard's sphere of interest and authority priority for research and assessment has been focused on four broad areas. The benefits (or lack of them) in output terms of a potential technical advance, the practicalities of an installation, work force factors and resource aspects as a whole. The same approach was applied to those technical innovations which <u>were</u> introduced into the Dockyard but after the discussion of how a particular advance related to the Dockyard's working practices further examination is pursued in Chapter Seven under the heading of "Specific advances in Portsmouth Dockyard" where site aspects and the inter relationships between various other applications are all examined together.

It would be naïve at this distance in time away from the period 1793 - 1815 to expect to produce conclusive answers to all questions of why particular technologies were not introduced but in those cases where there is more than one tenable hypothesis and an answer is important to the outcome of the thesis as a whole those hypotheses are advanced together with a "preferred" selection. This situation arises specifically in the case of the "Fibre" work where

Portsmouth appears to have been relatively backward in developing its rope making capability and certainly lagged behind other Royal dockyards. A case can be made for suggesting that an imaginative and well organised Navy Board decided to introduce new plant in one dockyard before introducing it into another and that case could be supported by the instances when Portsmouth took a lead role. However a case can also be made suggesting that Portsmouth's lack of enthusiasm for the rope making process was the yard's fear of fire. Three times between 1760 and 1776[6] the ropewalk had been burnt down and this can be supported by the fact that Portsmouth had a very early iron fire main[7].

1.3.7. Specific Technical advances in Portsmouth Dockyard. (Chapter 7): Following examination of which technical advances were exploited and which ones were not (and why) the last part of the evidence gathering and assessment is to look at the individual applications of technology in Portsmouth Dockyard for inter-actions, mutual exploitation and the pattern of them as a whole. A particularly good example of a sensible and very beneficial interaction was that a pump installed for driving machinery in one of the new mills during the day was used at night to pump water out of the dry dock reservoir. There are also a range of innovations where the introduction of one had a "cascade" effect and forced others - the dry dock complex is a good example of this where the greatly improved dry dock structure immediately caused the need for an advance in lock gates and a much quicker clearance of mud from the approaches to them.

1.3.8. Conclusions. (Chapter 8): The thesis is completed with the conclusions drawn from Chapters Two to Seven which together form the total picture of Portsmouth Dockyard's technical innovations between 1790 and 1815. The scope of those innovations stretches from steam powered comprehensive metal mills on the one hand, through a range of powered wood working machinery to the pumps for the dry docks and steam powered dredger to clear the approaches to them - all this in less than 20 years. As to the prime reason why the Dockyard achieved this position it is difficult to avoid the deduction that the rate and scale of development owed most to the vision and energy of a very small and select band of individuals of energy and vision. To them is due as much credit as to any of Nelson's "band of brothers" and the many Flag Officers whose names are firmly set in the history of the Navy and the Napoleonic Wars. The inescapable conclusion is that Portsmouth Dockyard does indeed rank amongst the most technically innovative sites in the country at that time and is entitled to a place in the Nation's history of technology.

1. Roger Morriss, *The Royal Dockyards during the Revolutionary and Napoleonic Wars*, Leicester University Press, Leicester, 1983, page 8.

2. E.A.M.Laing, *Steam Wooden Warship building in Portsmouth 1832-1852*, Portsmouth Papers No.42, Portsmouth, 1985, pages 3-8.

3. The first Portsmouth built screw propeller ship was Rifleman of 486 tons, launched in 1846. R.C.Riley, *The Industries of Portsmouth in the Nineteenth Century*, Portsmouth Papers No. 25, Portsmouth 1976, page 8.

4. Morriss, op. cit. n.1.

5. This was the theoretical number that ships of this size carried. At the Battle of Trafalgar on 21 October 1805, Victory carried 819 officers, crew and marines. John McKay, *The 100-gun ship Victory*, Anatomy of the Ship series, Conway Maritime Press, London, 1987, page 15.

6. Jonathan Coad, 'Historic Architecture of H.M. Naval Base, Portsmouth, 1700-1850', *The Mariner's Mirror*, (1981), 67, pp 20-21.

7. Cast iron water pipes had been laid around the Dockyard by 1805, and these had become part of a ring fire-main. Morriss, op. cit. n.1, p.48.

CHAPTER TWO
POLITICS, GOVERNMENT AND NAVAL ADMINISTRATION

2.1 General. In Britain the scale of investment in any of the Armed Services is dictated, in the first instance, by the immediacy of the threat perceived by the politicians of the day to the continuance, or advancement, of the Nations's prosperity and secondly by both the fears and aspirations of commerce - be that in terms of the protection of specific trades and/or the development of particular technologies which are dependent on the Government for funding. At the start of the 1790s political fear was undoubtedly growing over the intentions of Revolutionary France. Commercial concerns were also rising rapidly over the potential threats to the expanding export trade with the developing British Empire and lastly there was a small body of technical innovators who saw an armed conflict as the basis of potential funding for their various technological ambitions. The first two of these groupings were infinitely more powerful than the third although the influence of this third grouping cannot be ignored as far as the development of technology in the Royal Dockyards is concerned.This Chapter briefly reviews these considerations as a prerequisite to later discussions on the Royal Navy, its infrastructure and Portsmouth Dockyard in particular.

2.2 Politics. The British National Legislature consisted of three elements, the King, the Lords and the Commons. The crown was the pivot of authority for all governmental actions with the King as Head of State and George III took seriously the fact that his actions were constrained by the law and his actions were on behalf of his subjects. George III had genuine authority over central Government and ministers felt they were the King's servants in fact as well as in name[1]. The traditional pattern of eighteenth century British politics consisted of a stable administration, albeit with changing personalities of the same political persuasion, and an impotent minority in opposition. In spite of the terms 'Whig' and 'Tory' there were no political parties in the sense in which the twentieth century understands them, and the fundamental reason for this was that authority resided in a relatively small and tight-knit group separated from the rest of society which had the real power and influence in late eighteenth century Britain. A.D.Harvey describes it as " ...a hereditary social group, difficult if not impossible for non-members to join and distinguished from the rest of society for reasons not purely economic, and in that its members had a sense of equality amongst themselves[2]." Many but by no means all of this ruling group were inter-related, and for most young men there was a member of the family already established who would use influence on their behalf[3]. This influence, as well as applying to political careers also extended to the Church and the Army, where promotion was by purchase rather than by ability and experience. However the upper echelons of the Royal Navy were more open to men of ability rising within the service and it is reasonable to deduce that this arose from the fact that maritime environment was a harsh task master for the men in command of ships and there was no way that influence - political, social or economic - could readily disguise incompetence in the face of the power of wind and sea. The result was that professional competence was appreciated for what it was.

Eighteenth century Parliamentary groupings were organized on a 'patron and client' basis and small groups held personal loyalties to particular ministers or prominent men in opposition. Men with national or local power also had supporters who voted for them in Parliament, and in elections whilst they in turn fostered the careers of those who supported them. However if a minister left office, his supporters could lose their positions as well.

2.3 Government. The Government of late eighteenth century Britain dealt with the administration of diplomacy, regulation of foreign trade, revenue, defence, and law and order. The machinery of Government was small, with a handful of ministers presiding over departmental offices[4]. The leader of the government, as Prime Minister, also held office as First Lord of the Treasury but if the holder of this post sat in the House of Lords, there was a Chancellor of the Exchequer who was a member of the Commons. William Pitt, because he sat in the Commons, actually held both these posts and Table 2.1 lists the seven holders of the office of Prime Minster during the period[5].

The Home Office and Foreign Office had become separate departments in 1782 but the affairs of the colonies, which were of less importance after the loss of the American colonies, were administered firstly by the Home Office and later by the Secretary for War. The Secretary for War was established in 1794[6] and his office was responsible for the policies which were executed by the First Lord of the Admiralty, Commander-in-Chief of the Army and Master-General of Ordnance all of whom, at one time or another, had seats in the Cabinet. The three great officers of state, Lord President of the Council, Lord Privy Seal and Lord Chancellor also sat in the Cabinet, as did the President of the Board of Trade, Chancellor of the Duchy of Lancaster, Lord Steward of the Household and Lord Chamberlain[7].

TABLE 2.1 - PRIME MINISTERS ACROSS THE PERIOD

From	To	Prime Minister
1783	**1801**	**William Pitt the Younger**
1801	**1804**	**Henry Addington, 1st Viscount Sidmouth (son of the 1st Earl of Chatham's physician whose political career was sponsored by the Chatham (Pitt) family)**
1804	**1805**	**William Pitt the Younger (died in Office)**
1806	**1807**	**William Wyndham, Lord Grenville (Ministry of all the Talents)**
1807	**1809**	**William Cavendish-Bentinck, 3rd Duke of Portland**
1809	**1812**	**Hon Spencer Perceval, (died in Office - assassinated)**
1812	**1827**	**Robert Jenkinson, 2nd Earl of Liverpool**

Other posts of importance which were outside the Cabinet included the Paymasters of the Army and Navy, Lord Lieutenant of Ireland and the Attorney and Solicitor General.[8] By the late eighteenth century the public service was becoming more professional and all Government departments had administrative staffs whilst Clerks were becoming salaried servants of the Crown, rather than assistants to a minister. Reforms to the existing administration had been initiated by Lord North in 1776[9], in a Treasury minute on the training of departmental clerks and their promotion with reference to their ability not just their seniority. Later, in 1780[10], the Board of Commissioners, set up by Lord North, to examine the whole field of public expenditure and accounting was particularly critical of the fee system. Subsequently payment of clerks by salaries rather than by fees spread from the Treasury to the other main government departments.

2.4 The Admiralty Board. The chain of command between the Crown and the Royal Dockyards passed through the Admiralty Board and its sub-boards. The Admiralty board were "....the Lords Commissioners for executing the office of Lord High Admiral of Great Britain[11]," and was led by the First Lord (see Table 2.2 for the holders of this post during the period), a politician, or a senior admiral with a seat in Parliament, or the House of Lords, although the First Lord's post was always a political appointment. The Board was responsible for naval strategy and tactics, the movements of fleets and individual ships, allocation of resources and the appointment and promotion of all commissioned officers. They supervised the activities of the sub-boards (shown diagrammatically in Figure 2.1) who were the Navy, Victualling, Transport and Sick and Hurt. In the period 1790 - 1816 there were no less than nine First Lords of whom only two were Naval officers and Admirals - John Jervis, Earl St.Vincent and Charles Middleton, Lord Barham[12]. Furthermore Table 2.3 shows that between 1801 and 1812 only two men held the office for more than two years and hence it would seem that they were not as influential in the long term development of the Royal Navy and its infrastructure as the popular history books might lead one to believe. However there were other personalities who held office within the Admiralty who undoubtedly had a profound affect on the shape and development of the dockyards and Samuel Bentham comes immediately to mind. The Admiralty Board was based in Whitehall. In 1795, a new office that of the Inspector General of Naval Works was created and its purpose was to address improvements in the construction and fitting out of ships, the buildings within the Dockyards, the introduction of new machinery to them and improvements to the existing machinery and tools.

TABLE 2.2 - FIRST LORDS OF THE ADMIRALTY ACROSS THE PERIOD

From	To	First Lord
1788	**1794**	**John Pitt, 2nd Earl of Chatham (Elder brother of the Prime Minister)**
1794	**1801**	**2nd Earl Spencer**
1801	**1804**	**1st Earl St Vincent (previously Admiral Sir John Jervis)**
1804	**1805**	**Henry Dundas, Ist Viscount Melville**
1805	**1806**	**Lord Barham (Admiral Sir Charles Middleton - ex Controller of the Navy)**
Feb 1806	**Sept 1806**	**Charles Grey, 2nd Earl Grey**
1806	**1807**	**Thomas Grenville (brother of the Prime Minister)**
1807	**1810**	**Henry Phipps, 3rd Earl of Mulgrave**
1810	**1812**	**Charles Yorke**
1812	**1827**	**Robert Saunders Dundas, 2nd Viscount Melville**

TABLE 2.3 - CONTROLLERS OF THE NAVY ACROSS THE PERIOD

From	To	Controller of the Navy
1778	1790	Sir Charles Middleton
1790	1794	Sir Henry Martin
1794	1806	Sir Andrew Hammond
1806	1806	Henry Nichols
1806	1816	Sir Thomas Thompson

THE ADMIRALTY BOARD AND ITS SUBORDINATE BODIES

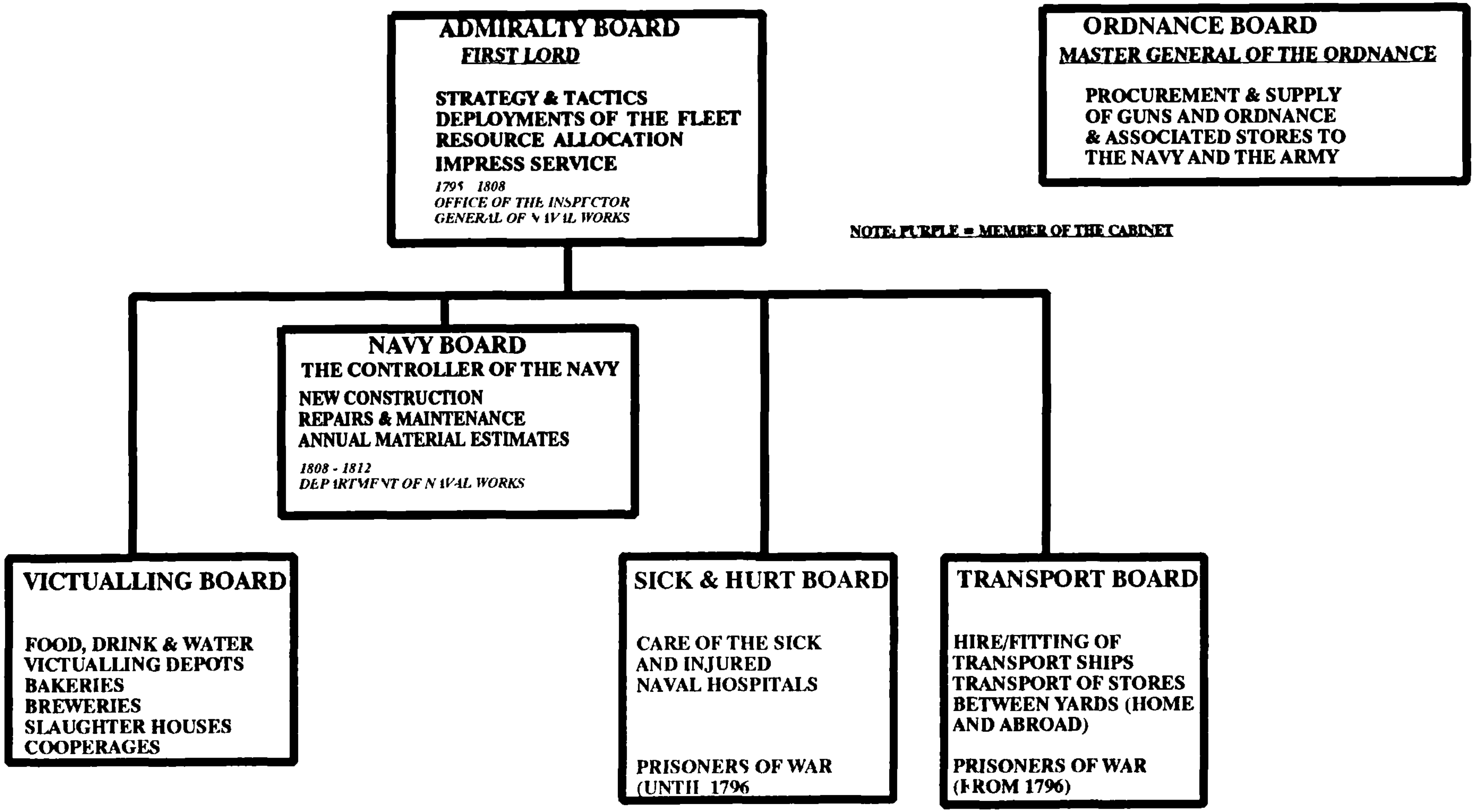


FIGURE 2.1

Originally planned to have a staff of 15 including posts for an Architect and Civil Engineer, Mechanist and Chemist as well as the Inspector General[13] and Samuel Bentham, who had proposed this organisation to the Admiralty Board, was invited to become the Inspector General[14], a post he held until 1812.

Early in life Bentham had been apprenticed to the Master Shipwright at Chatham[15] and quickly showed a positive affinity with technical matters but being unable to obtain a suitable post in the Dockyards due to his lack of experience, Bentham decided to travel and broaden his experience. Between 1780 and 1791, he served in Russia[16], organizing and supervising manufacturies of rope, canvas and iron products for Prince Potemkin, a leading member of the Russian Court. However, after the death of his father in 1791, Bentham did not return to Russia but instead visited manufacturies to keep himself abreast of the latest technical developments in Britain. It is something of a puzzle as to the means by which a man who had been abroad for eleven years could so readily become part of the governmental circle. Perhaps, his half-brother Charles Abbot who was Speaker of the House of Commons[17] promoted the interests of a family member and this may well explain this anomaly. Another example of this use of connections to further a career is that of Marc Brunel, one of the engineers associated with Bentham on Dockyard projects, who obtained an introduction through his brother-in-law, Roger Kingdom who was a Navy Board clerk[18].

2.4.1. Navy Board: The most senior and important of the Admiralty sub-boards was the Navy Board, an essential part of the chain of command between the Admiralty Board and the dockyards. Although it worked closely with the Admiralty Board, it had considerable independence and it consisted of a combination of naval officers, shipwright officers and civilian administrators. As its members were civil servants not politicians, they were more permanent than the members of the Admiralty Board who were political appointees. The head of the Navy Board called the Controller was a Senior Naval Officer but he was expected to sit in the House of Commons as the representative of a naval town or port - Table 2.3 shows the five holders of this post between 1778 and 1816[19]. At any one time, there were two or three surveyors who were Master Shipwrights of long experience and who were responsible for ship design, building and maintenance. On the purely administrative side, the Clerk of the Acts, served as the Board Secretary and there were three Controllers of the Storekeepers, Victualling and Treasurers accounts. Commissioners of the Royal Dockyards were also members of the Board[20]. The Navy Board was charged with building, equipping and maintaining the ships of the Royal Navy and its responsibilities included all the technical and financial administration associated with that. The Board examined and appointed warrant officers such as boatswains, carpenters, and cooks and appointed warrant officers examined by other bodies such as ship's masters and surgeons. It is more significant from the viewpoint of this thesis that it oversaw the Royal Dockyards, and the provision of new building as well as maintenance of existing buildings, whilst it also provided advice and guidance on professional matters to the dockyard officers. Lastly, using information provided by the Dockyards, the Navy Board prepared the Annual Estimates for the Admiralty Board to present to Parliament. The annual Estimates were in three parts;[21] the Ordinary estimate which was a specific amount for maintenance of ships and dockyard facilities, second was the Extra estimate used for the building of new ships and the reduction of the backlog of maintenance and debt, and thirdly the estimate for the number of seamen and marines voted in any year which determined the size of the Operational Fleet.

2.4.2. Victualling Board: The next most important sub-board was that of Victualling[22] which had close working relations with the Navy Board and consisted of seven commissioners who were based at Somerset House in London. Although its main supply depot was at Deptford, there were depots in all the major dockyards. The duties of this board included supplying fresh food, drink and water to all ships in harbour and at sea, and it discharged these through its appointed agents and by negotiating contracts with suppliers. The Board ran the victualling depots which included bakeries, breweries and facilities for slaughtering and salting meat as well as cooperages to manufacture casks for the storage of foodstuffs and water on board ship. It also appointed and regulated the pursers of the Fleet, who were responsible for administering food supplies on board ship and were empowered to purchase fresh food in foreign ports. Before its abolition in 1832 the Victualling Board pioneered improvements in diet including the introduction of canned food.

2.4.3. Transport Board: Between 1690 and 1724, when its responsibilities were transferred to the Dockyards, a Transport Board had existed to hire and equip ships for the transportation of troops. As the result of criticism of the amounts of time dockyard officials has spent surveying ships to be used as transports during the American War of Independence, the Board was re-created in 1794 at the outbreak of the French Wars[23]. It consisted of three senior naval officers with agents and surveying staff and in 1796, it assumed responsibility for the care of prisoners of war, previously undertaken by the Sick and Hurt Board.

2.4.4. Sick and Hurt Board: The Sick and Hurt Board was primarily responsible for the appointment of ship's surgeons, the provision of their supplies and the running of naval hospitals[24] although it had been responsible for prisoners of war until 1796. A Parliamentary enquiry of 1804, into debts incurred by the Board recommended its merger with the Transport Board which at that point had a reputation for efficiency and this was implemented in 1806[25].

2.4.5. The Impress Service: This Service was managed from within the Admiralty as distinct from being a separate and subordinate Board. It dealt with all forms of recruitment and had three functions of roughly equal importance[26]. The first was the recruitment of volunteers and the second was the acquisition of non-volunteers or "pressed men" (hence the term press gangs) who ideally were trained seamen from the merchant fleet but in times of war the Impress Service took whoever they could get - including jail prisoners. Lastly the Service acted as a police force for the apprehension of stragglers who were seamen allowed ashore but who failed to return to their ships on time or before sailing and for deserters who were men who did not intend to return to their ships at all.

All the fighting equipment from ships guns to cutlasses used by the Royal Navy was the property of the Ordnance Board which was independent of the Admiralty Board and of similar status[27]. It was led by the Master-General of Ordnance who like the First Sea Lord, had a seat in the Cabinet. The Ordnance Board maintained depots and magazines in major dockyards, so that fighting equipment and stores were issued to ships before sailing and returned when a ship went into refit or Ordinary.

2.5 Influential National Bodies. It was possible and indeed accepted practice, for bodies of national standing to influence Parliament's decision making. Prime examples in the maritime sphere were Lloyds of London and the great overseas trading companies such as the East India Company.

2.5.1. Lloyds: The Admiralty worked closely with Lloyds; a world centre of marine intelligence and insurance, consequently, Lloyds recommendations on trade protection were given careful consideration by the government and were influential in ensuring the success of the Admiralty's convoy system with merchant shipping since Lloyds was in a position to ensure that merchants ships complied with the convoy system because, if they did not, their insurance premiums rose. With the introduction of the Convoy Act of 1793 and the Compulsory Convoy Act of 1798, convoying became obligatory for all foreign-going merchant ships and heavy fines were imposed on convoy breakers. After 1806, Lloyds co-operated with the Admiralty and the merchant fleet to devise new convoy routes, establish entrepots and maintain the flow of exports into the European markets closed under Napoleon's Continental blockade.

2.5.2. Trading Companies: had their origins in the custom of medieval merchants bonding together for mutual protection and profit. Groups of merchants with particular trade interests were able to put pressure on the Government for preferential treatment in defence of that trade. Furthermore the companies had direct influence in the City as their trade produced a large proportion of the Government's revenue through duties and excises. One of the most important trading companies from the point of view of this thesis was the East India Company, which was formed in 1600 to trade in pepper, spices, tea, muslins, calicoes, silks and porcelain. By the late eighteenth century, the Company, which dominated the Indian and Far Eastern trades, had been drawn into activities beyond the normal scope of trading companies with its acquisition and administration of territory on the Indian sub-continent[28]. The Company supported the Royal Navy by allowing ships to use their facilities in Bombay, Madras and Calcutta and additionally it was a source of ships; either by building warships on the Navy's behalf[29] or by the sale to the Navy of East Indiamen which were used as storeships or transports[30]. East Indiamen were larger than the average merchantmen since they were designed to carry large cargoes for long distances.

2.6 Government Overseas Foreign Policy. The vital elements in British foreign policy were the defence of the realm and the promotion and protection of its trade. A dislike and distrust of the French had been general since the time of Louis XIV[31] and to this was added, by the end of the eighteenth century, a dread of the new French revolutionary political ideas which France was trying to spread throughout Europe. The British Government was particularly fearful of the export of France's increasing internal violence which lead to the overthrow and subsequent execution of the French monarch and his family as well as the larger September massacres. By 1792, the British Government was deeply concerned also by growing French aggression to her neighbours such as the Low Countries since it was believed that this could lead to an upset in the European balance of power[32]. In 1793 France declared war on Britain and Pitt saw his Nation's aim for the war not as prejudice or fear but as ".....security - security against a danger the greatest that ever threatened the world[33]". Nevertheless, once the war had started, Britain was prepared to use the situation to her commercial advantage. Extension, as well as security, of trade had been a major objective in every war since the seventeenth century and in this area Britain's aims were not simply limited to a response to a French threat to the country's increased trade and the exportation of the manufactured products of the Industrial Revolution.

During the eighteenth century trading rights were at the heart of the five wars fought between Britain and France. These were the wars of Spanish (1702-1713) and Austrian Successions (1740-1748), the Seven Years War (1756-1763), the war for American Independence (1775-1783) and the war against Revolutionary France (1793-1802) which was to continue against Napoleonic France from 1803 to 1815. In the first three of these wars; those of Spanish and Austrian Succession and the Seven Years War, Britain's commerce gained at the expense of both her enemies France and Spain, and her ally Holland[34]. The war of 1740 to 1748, began as a war with Spain over trading rights in the Spanish Indies but it broadened into a conflict with France whilst the main objective of the Seven Years War (1756-1763) was to protect Britain's lucrative trade with her American colonies from the same country.

Britain was defeated in the American War of Independence, and her colonies were lost but contrary to the fears of British politicians and merchants, there was no great loss of trade and America continued to import British manufactures in large quantities and export raw materials to her[35]. Indeed, the Jay Treaty signed by America and Britain in 1795, conferred most-favoured nation status on this trade. However there were two problems in the relationship which were not resolved and these were to result in America declaring war on Britain in 1812. Firstly Britain did not recognize the American laws of naturalization, so American seamen were liable to impressment into the Royal Navy and secondly Britain's policy of stopping and searching neutral shipping for goods likely to aid her enemies was strongly objected to by Americans. The war closed a lucrative market to British goods and caused fluctuations in the supplies of American raw materials such as cotton to Britain, although fortunately American corn, on which the Peninsular army depended, continued to be shipped into Spain.

2.7 Government European Foreign Policy. British European foreign policy was shaped by Britain's need for allies to fight against France. In earlier eighteenth century wars, especially the Seven Years War, Britain had frustrated France's European objectives by providing subsidies to her continental allies to pay for their armies to undertake the land war on Britain's behalf. At the same time, Britain disrupted French commerce by defeating her at sea, and using small armies to seize her colonies. From 1793 to 1802, what had been a successful policy in earlier wars, had failed to check the French advance across Europe. The subsidy policy's ineffectiveness was made worse by Britain's poor relations with her allies as a consequence of a division of their individual war aims. From 1793 to 1800, Prussia, Russia and Austria were more interested in possible gains of territory in Poland, than in the war against France; they were prepared to accept destruction of their large armies in order to achieve their long-term goals. Although Britain's strong and increasing trading base made it possible for her to pay subsidies in gold to her allies, there were great risks. With the renewal of war between Britain and France in 1803, security and trade remained the principal concerns of the British government and the growing size of the manufacturing sector with its economic vulnerability meant that with Napoleon's efforts to isolate and destroy British commerce, security of the realm and security of trade became synonymous. By 1807 Napoleon's continental power had increased to the extent that he had virtually isolated Britain who was not able to gain a foothold on European soil until an expeditionary force was sent to the Iberian Peninsular in support of the Spanish army in 1808. There Britain's involvement slowly became a growing commitment which eventually turned into a major land campaign and naval logistic operation. Ultimately the Peninsular war was to prove fundamental to Napoleon's defeat and the ending of the war.

2.8 Government Financial Policy. Probably the second major preoccupation for the British government during the wars against France from 1793 to 1815, was the cost of the war, and raising sufficient revenue to meet that cost. Indeed it was to be the most costly and the longest war that Britain had ever fought but most significantly, it was one of the few wars in which the British Government accepted that it would have to pay its debts at the time rather deferring them to a later date. Despite the fact that the Navy was permanently in debt and the need for financial economy was pressing, the Royal Navy substantially received the funding it sought from Parliament to prosecute the war and that funding included the finance required to operate Portsmouth Dockyard. It is worth noting that at the height of the war between 1807 and 1813, the Naval estimates were running at an annual level of around 19 million pounds[36].

The Bank of England had to have sufficient gold to cover all promissory notes and the export of large quantities of gold to Britain's Continental Allies in 1797, created a shortage. A number of small banks collapsed and there was a loss of confidence which was only stemmed when William Pitt stopped the Bank of England honouring its notes in cash and paying with banknotes instead. This was a revolutionary new departure in economic terms since, effectively, Britain's internal trade came off the gold standard. No attempt was made by the government or banks to regulate the issue of banknotes and this created sufficient inflation to stimulate trade by creating a monetary situation where commercial expansion was possible in spite of heavy taxation and the disruptions in trade due to the war[37]. The real benefits of the war were derived from this suspension of cash payments - an emergency expedient - and the traditional policy, going back to the time of Queen Elizabeth I, of systematic interference with enemy trade. Interestingly, the phenomenal cost of the war in 1811 amounted to no less than 16% of the gross national income. Just over one hundred years later in 1915[38] the cost of the war was an identical percentage.

2.9 Industrial Development. Despite the massive diversion of labour from agriculture and industry into both full-time service in the Army and Navy and part-time service in the Militia and Volunteers, trade and industry continued to expand. Industrialization across Europe and America had gathered speed from the 1750's and Great Britain led the way with developments in the cotton, iron and mining industries and the large-scale manufacture of chemicals. Many were based on the application of steam power and between 1750 and 1780, the number of new inventions patented each year multiplied by six[39]. The use of machinery and the application of steam power created a need for a building designed to accommodate them and changed the working structure from domestic-based industries to those of the factories. However, on the negative side, the war induced fluctuations in trade and brought stagnation in some sectors as well as a decline in real earnings for the workers which led to food riots and industrial unrest[40]. Table 2.4 attempts to illustrate the general level of technology in Great Britain by 1790 and this is expanded on in Chapter 6.

Chapter 7 discusses the specific technical advances made in Portsmouth Dockyard. Primarily these were applications of new technologies rather than outright new inventions and came about as a consequence of the Office of the Inspector General of Naval Works investigating the various advances being made in commercial industry with a view to identifying those of potential value to the Royal Navy. Thus it was Samuel Bentham and his small team who effectively constituted the interface between the Service and Industry and it was this organisation that then went on to obtain approval and funding to procure the necessary equipment. Subsequently they then managed its development and installation in the Royal Dockyards.

TABLE 2.4 - STATE OF INDUSTRIAL DEVELOPMENT

Date	INVENTION	PERSON
1745-50	Manufacture of crucible Steel	Benjamin Huntsman
1760's	Developments in cotton spinning machinery	Arkwright & Hargreaves
1761	Manchester-Worsley Canal opens	James Brindley
1770	Screw-cutting Lathe	Jesse Ramsden
1776	Steam engines used commercially	
1781	First rotative steam engine	James Watt
1784	Puddling process for making Iron	Henry Cort
1790	Civil engineers using iron components	

2.10 Government Defence Policy. If the British Government's two principal aims in the conduct of the war against France were defence of the realm by the overthrow of France and the security and extension of Britain's trade, the instruments to carry out this strategy were her armed forces.

2.10.1.Army: With a comparatively small population, Britain could not, and would not, carry out the large-scale mobilisations seen on the Continent especially as there was a deep-seated dislike of standing armies in Britain caused by distrust of the expansion of military force under the Crown's control. As it had an enduring preoccupation with commerce and the colonies, the British Government tried to fight Revolutionary France with the methods which had proved successful against Bourbon France in the 1750's and 1760's. Firstly large-scale land warfare on the Continent was to be conducted by our allies supported by British subsidies and secondly the Government looked to small-scale expeditions by the British Army against French (and her allies) colonies, which when captured, could be used as bargaining counters in the subsequent peace negotiations. What the British Government was unable to understand was the fact that in this war France had no limits to her war objectives or to the scale of military resources she was prepared to commit. As a result the British Government singularly failed, until almost when success in the Iberian Peninsula was looking them in the face, to devise suitable land warfare strategies on the European Continent to combat Napoleon.

2.10.2. The Royal Navy: The strategic choices for the use of the Royal Navy were more straight forward than those surrounding land forces. Firstly, if the Royal Navy could destroy the enemy's fleet, this would have two consequences - it would make the invasion of Britain impossible and secondly it would remove the protection from the French overseas merchant trade, which would then be unable to perform its function of creating wealth for the French state. Secondly there was the well proven use of the Royal Navy to attack French overseas trade thus profiting our own and helping to destroy the enemy's economy. Thirdly the wars of the eighteenth century had shown that British merchant shipping, and hence trade, was vulnerable to "raiders" and "privateers" and therefore both that shipping and the countries and islands with which trade was conducted needed to be protected. As that trade, and the revenues which flowed from it, expanded around the world the protection requirement grew and the City of London and the National Institutions were quick to ensure that the Government did not forget this.

However naval activity on its own did not weaken the French hold on the Continent and it increased rather than decreased Napoleon's commitment to war with Britain. By 1805, the situation had been reached in which a sea power was trying to defeat a land power, and it was not until the Navy was used to put in place, and sustain on the continent, a sizeable army which could oppose and defeat any of those of France, that the war as a whole turned in favour of Britain and her allies.

What can be said with certainty is that Britain's success in its long fight against Napoleonic France was built on three pillars. The first was the country's financial strength, arising from its position as the world leader in the technological sphere. Second, the Royal Navy's capability to project, protect and sustain the country's interests across the globe and third, the ability of the British Army and Navy acting together to exploit the benefits that maritime superiority gave them against a purely land based force, no matter what its size was.

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2. A.D.Harvey, *Britain in the early Nineteenth Century*, Batsford, London, 1978, page 6.

3. Harvey, op. cit., n. 2, pp. 6-10.

4. Christie, op. cit., n. 1, p. 23.

5. J. Steven Watson, *The Reign of George III, 1760-1815*, Oxford History of England edited by Sir George Clark, Clarendon Press, Oxford, 1960, Volume 12, pages 578-583.

6. Ibid., pp. 578-583.

7. Ibid., pp. 578-583.

8. Steven Watson, op. cit., n. 5, pp. 578-583.

9. Christie, op. cit. n.1, p. 23.

10. Ibid., p.24.

11. Jonathan Coad, *The Royal Dockyards, 1690-1850*, Scolar Press, Aldershot. 1989. page 23.

12. *Admiralty Officials 1660-1870*, Compiled by J.C.Sainty, Office Holders in Modern Britain, Institute of Historical Research, University of London, London, 1975, Volume IV.

13. ADM 1/3525, Minute of 29 February 1795, Public Records Office, Kew.

14. ADM 1/3525 Note of 3 August 1796 signed by Bentham says "My service commenced in April 1795. My warrant entitling me to salary was dated 25 March 1796."

15. Lance Day and Ian McNeil (eds), *Biographical Dictionary of the History of Technology*, Routledge, London, 1996, pages 56-57.

16. Ian R. Christie, *The Benthams in Russia 1780-1791*, Anglo-Russian Affinities series, Berg, Oxford, 1993, pages 54-65.

17. Ibid., pp.1-20.

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20. Ibid., pp.9-14.

21. Brian Lavery, *Nelson's Navy, the ships, men and organization, 1793-1815*, Conway Maritime Press, London, 1989, page 21.

22. Ibid., p.21.

23. M.E.Conden, 'The Establishment of the Transport Board - A Subdivision of the Admiralty - 4 July 1794', *The Mariner's Mirror*, London, 58, pp 69-84.

24. Lavery, op. cit. n.21, p.21.

25. Roger Morriss, *The Royal Dockyards during the Revolutionary and Napoleonic Wars*, Leicester University Press, Leicester, 1983, page 8.

26. N.A.M.Rodger, *The Wooden World, An Anatomy of the Georgian Navy*, Collins, London, 1986, page 165.

27. Coad, op. cit. n.11, pp. 245-246.

28. J.Steven Watson, op. cit. n.5.

29. David Lyon, *The Sailing Navy List*, Conway Maritime Press, London, 1993, pages 72, 82 and 115.

30. Ibid., pp.241 and 270.

31. Louis XIV reigned from 1643 to 1715. In Britain, this period runs from the start of the Commonwealth in 1649 to the death of Queen Anne in 1714.

32. Harvey, op. cit. n.2, pp.301-306.

33. *The Parliamentary History of England from the earliest period to the year 1803*. 36 vols. Volume 34 col 1442. 17 February 1800.

34. C.P.Hill, *British Economic and Social History 1700-1982*, Edward Arnold, Bath, 1985, 5th edition, page 57.

35. Ibid., p.57.

36. William Laird Clowes, *The History of the Royal Navy from the Earliest Times to 1900*, William Clowes, London, 1900, Volume 5, page 9.

37. Harvey, op. cit. n.2, pp.320-321.

38. Harvey, op. cit. n.2, pp.334-339.

39. T.K.Derry and Trevor I.Williams, *A Short History of Technology*, Oxford University Press, Oxford, 1982, page 281.

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CHAPTER THREE
NAVAL REQUIREMENT - FLEET OPERATIONS & COMPOSITION

3.1. General. To meet the dictates of the Government, and the pressures on that from influential sections of Commerce and Society, the Royal Navy had developed, by the mid eighteenth century, into a highly complex organisation with two major interdependent, but markedly different, structures. On the one hand there was the shore infrastructure, without which the Navy would not have existed at all, and on the other there was a range of different tasks which gave rise to a number of discrete ship types with varying but complementary operational capabilities. This Chapter looks firstly at the Shore Infrastructure and then at the tasks of the Fleet before moving on to the operational purposes of the ship types and thence the size and composition of the Fleet as a whole from 1790 to 1815. Thereafter Chapter Four examines the actual work done in Portsmouth Dockyard on individual ships in those years.

3.2. Royal Dockyards and Naval Bases. By the start of the Revolutionary War against France in 1793, the Royal Navy was operating across the globe. There were British ships on foreign stations in the Mediterranean, West Indies, North America and the Indian Ocean. At the same time, voyages of exploration were taking place to Australia, New Zealand and through the Pacific Ocean[1]. These deployments were only made possible as a result of the work done by the Royal Dockyards, for unless wooden ships were maintained and repaired regularly they quickly suffered from rot and decay and become useless for the tasks they were required to undertake. The functions of the Royal Dockyards were to build, or supervise the building of, all new ships for the Royal Navy and concurrently to refit/repair the existing ships. In addition the Royal dockyards maintained the Reserve Fleet, or Ships in Ordinary as they were called at that time.

The locations of the Royal Dockyards had evolved over three centuries of maritime warfare, and by the late eighteenth century there were six major dockyards (see Figure 3.1) serving the needs of the Royal Navy and located on the River Thames or the South Coast of Britain[2] where Portsmouth (see Figure 3.2) was.

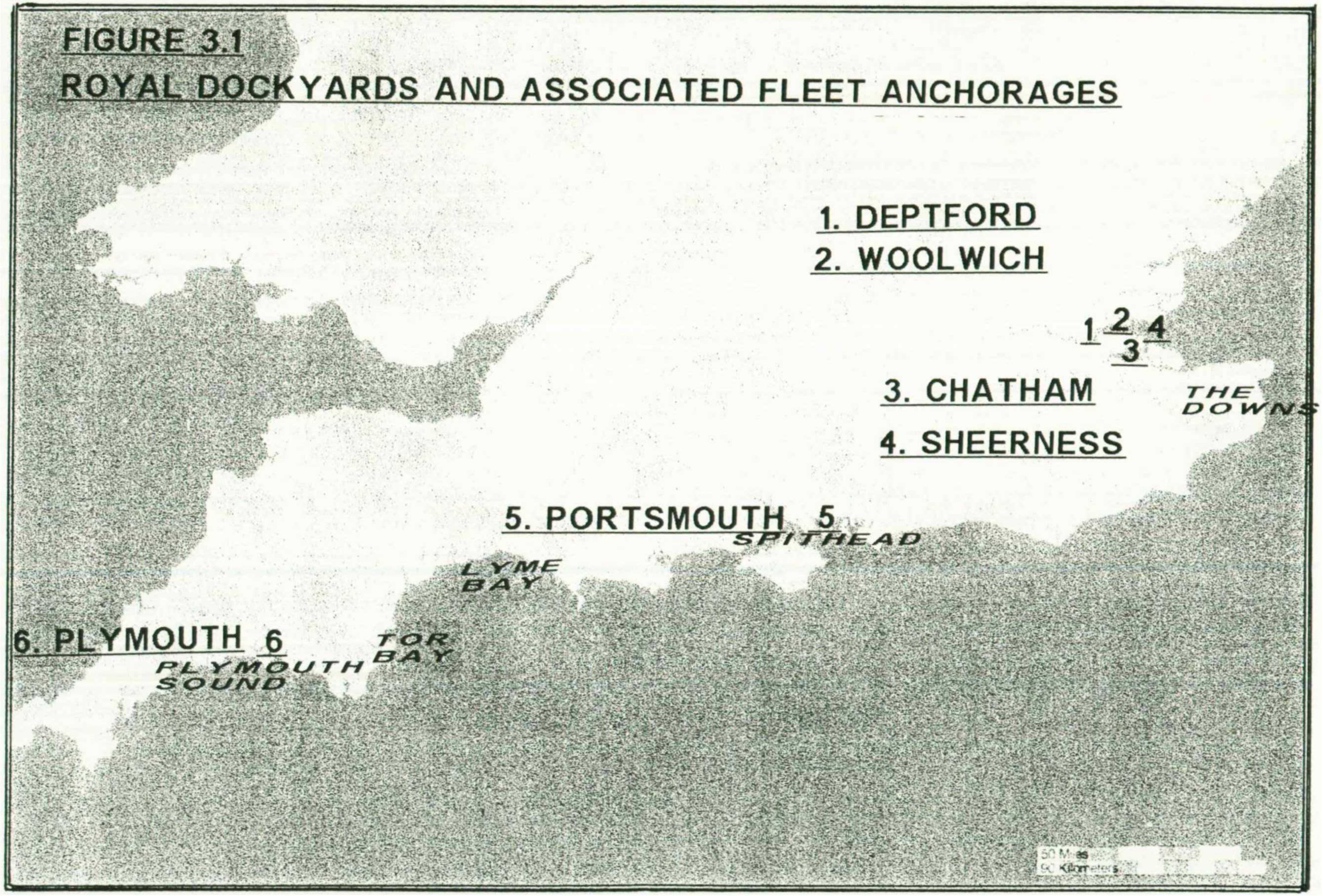


FIGURE 3.1
ROYAL DOCKYARDS AND ASSOCIATED FLEET ANCHORAGES

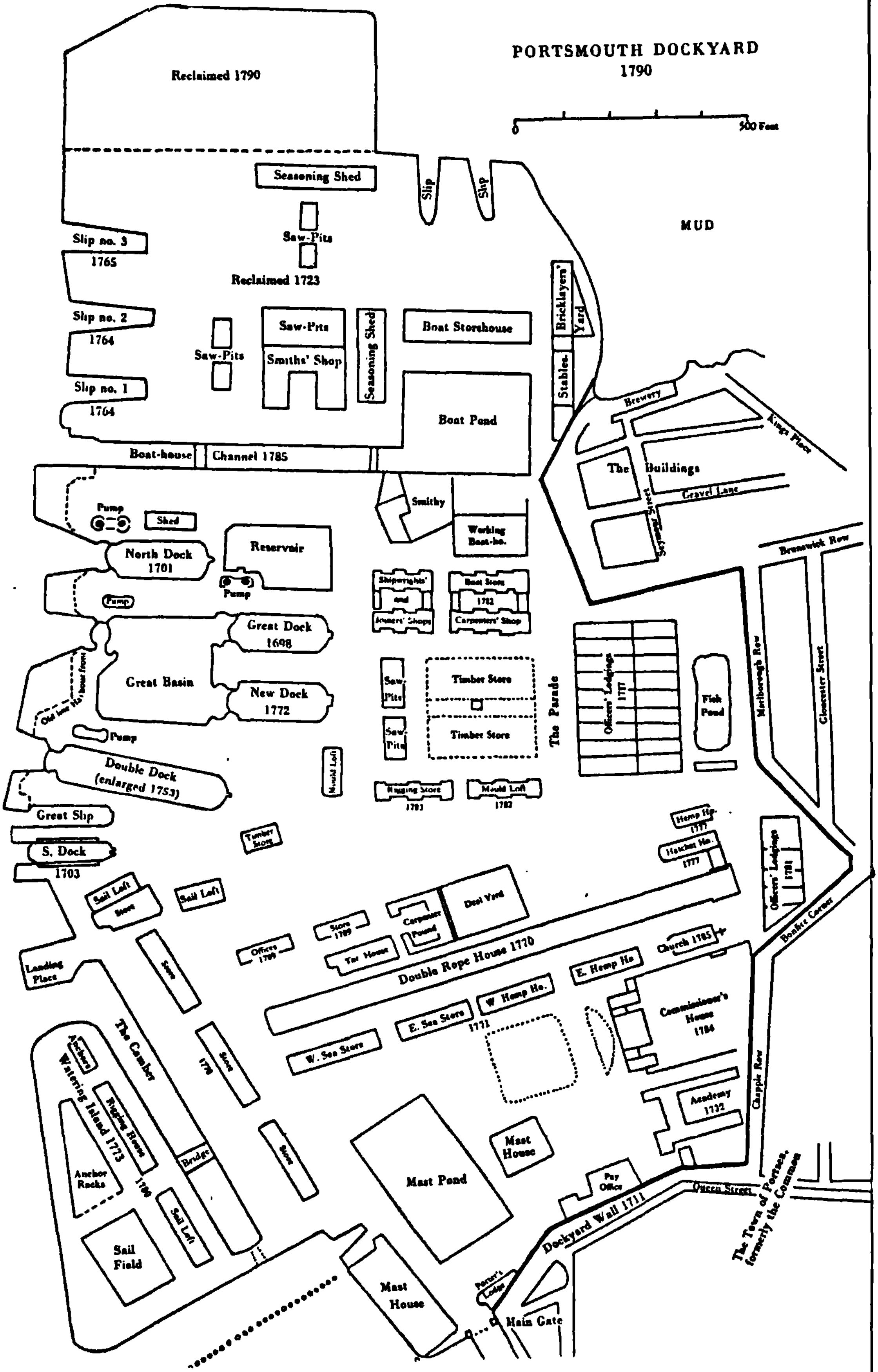

PORTSMOUTH DOCKYARD
1790
0
500 Feet
Reclaimed 1790
Seasoning Shed
Slip
Slip
MUD
Saw-Pits
Slip no. 3
1765
Reclaimed 1723
Slip no. 2
1764
Saw-Pits
Smiths' Shop
Seasoning Shed
Boat Storehouse
Bricklayers' Yard
Stables
Slip no. 1
1764
Saw-Pits
Boat Pond
Brewery
Kings Place
Boat-house
Channel 1785
The Buildings
Gravel Lane
Smithy
Pump
Shed
Working Boat-ho.
Seymour Street
North Dock
1701
Reservoir
Brunswick Row
Pump
Pump
Boat Store
1782
Carpenters' Shop
Great Dock
1698
Great Basin
New Dock
1772
Timber Store
Timber Store
The Parade
Officers' Lodgings
1717
Fish Pond
Marlborough Row
Gloucester Street
Pump
Double Dock
(enlarged 1753)
Mould Loft
Rigging Store
1783
Mould Loft
1782
Great Slip
Timber Store
Hemp Ho.
1771
Hatchet Ho.
1771
Officers' Lodgings
1781
S. Dock
1703
Sail Loft
Store
Sail Loft
Deal Yard
Store
1789
Carpenters' Pound
Offices
1789
Tar House
Double Rope House 1770
Church 1785
Bonfire Corner
Landing Place
Store
E. Hemp Ho.
W. Hemp Ho.
Commissioner's House
1784
E. Sea Store
1771
The Camber
Store
1776
W. Sea Store
Anchors
Watering Island 1773
Rigging House
Academy
1732
Chapple Row
Bridge
Anchor Racks
1790
Store
Mast House
Mast Pond
Pay Office
Queen Street
The Town of Portsea, formerly the Common
Sail Loft
Sail Field
Dockyard Wall 1711
Mast House
Porter's Lodge
Main Gate

FIGURE 3.2

Each dockyard was a complex site embracing such facilities as the rope-house, sail-loft, building slips, smithies and many small workshops as well as large areas taken up with storing and seasoning timber and the associated saw-pits. Furthermore, as the dockyards had to supply all items needed to keep the ships of the fleet operational, parts of them were devoted to manufacture as well as storage of purchased items. Close to the Dockyard were other essential establishments such as the Victualling and Ordnance Depots, Marine Barracks and Hospitals for the sick and injured. Associated with the Royal Dockyards there were Fleet Anchorages (Figure 3.1) an inshore sheltered sea area where the ships of the Fleet could be safely anchored, in some numbers, even in the worst of weather. Here there was sufficient space between the anchored vessels so that they could swing with the tide without the risk of entanglement, whilst being sufficiently close to shore for support craft from the nearest Royal Dockyard/Depot to reach them readily with water, food, maintenance personnel and other necessities but without the problems of their crews deserting. Some anchorages had local depots specially set up for this purpose, thus ships in the Downs off the Kent coast were supplied from a depot at Deal, and those in Tor Bay were supplied from Brixham[3].

3.2.1. Royal Dockyards in Britain: The Dockyard closest to London, centre of naval administration and principal market for naval stores was Deptford - see Figure 3.1. This was the main victualling yard and centre for distributing naval stores and other items required by the Dockyards, although by the late eighteenth century, the Thames was too silted up for the largest ships to enter Deptford Yard[4]. The next yard down river was Woolwich, a small yard on a confined site which was a long way from the sea and already beginning to decline.

Chatham, the most important of the Thames yards, was actually situated on the River Medway and, having good access to the North Sea, it had been the premier base for the fleet in the wars against the Dutch. Although there was ample room to expand the site, the Medway needed regular dredging to remove the accumulation of silt which made entry to and exit from the yard difficult. The Dockyard's importance began to decline as the principal theatre of naval operations moved westwards but it remained the 'home' of the North Sea Squadron with it s fleet anchorage at the Nore[5]. Sheerness, which originated as an extension to Chatham, was nearer the mouth of the river and the fleet anchorage but the site was small and exposed to the prevailing south westerly winds so that ships at anchor were subject to damage in heavy seas[6].

As the Royal Navy's main theatre of operations changed from maritime wars against Holland to war against France on a global scale, coupled with operations across the Atlantic, the importance of the two South Coast dockyards at Portsmouth and Plymouth increased. By the end of the American War of Independence, (1774-1783), these two South Coast dockyards had taken precedence over the Thames yards in the day to day maintenance of the fleet.

For the period of the Revolutionary and Napoleonic Wars, 1793 to 1815, Portsmouth's primary role was that of refitting and repairing ships. There were actually five building slips available[7] but the Dockyard undertook very little building work during these years. Plymouth acted as support base for ships blockading the Northern French ports and also undertook refit and repair work whilst the dockyards on the River Thames progressively became more concerned with the provision of supplies to the Fleet and building new ships for the Navy than they did with refit and repair work.

3.2.2. Portsmouth Dockyard: Portsmouth had been a naval base since the end of the fifteenth century, and had always been used as a point of departure and base in wars against France. It has a good sheltered harbour and anchorage which had double high tides due to the flow up the English Channel first entering Portsmouth from the West of the Isle of Wight and then, some one hour later, from the East of the Island. The actual fleet anchorage at Spithead lay between Portsmouth and the Isle of Wight and was sheltered from the prevailing westerly winds. It was close enough to Portsmouth Dockyard for ships to be readily watered, victualled and stored from there. There was an additional anchorage in St Helens Roads, well sheltered from the South since it was close in to the Isle of Wight but it was further from the Dockyard than was Spithead.

Portsmouth Dockyard lies to the North of Portsmouth Town (Figure 3.3) from which it was separated by the Hard. The Victualling and Ordnance Boards had depots in Portsmouth and access to the harbour. The Ordnance Yard or Gun Wharf lay to the south of the dockyard with the length of the Hard between them[8]. Until the 1760's all their facilities had been on the Portsmouth side of the harbour, including the fifteenth century Square Tower at the west end of High Street which was the principal powder magazine. However in the interests of safety, the magazine was relocated on the western side of the harbour to a site called Priddy's Hard[9].

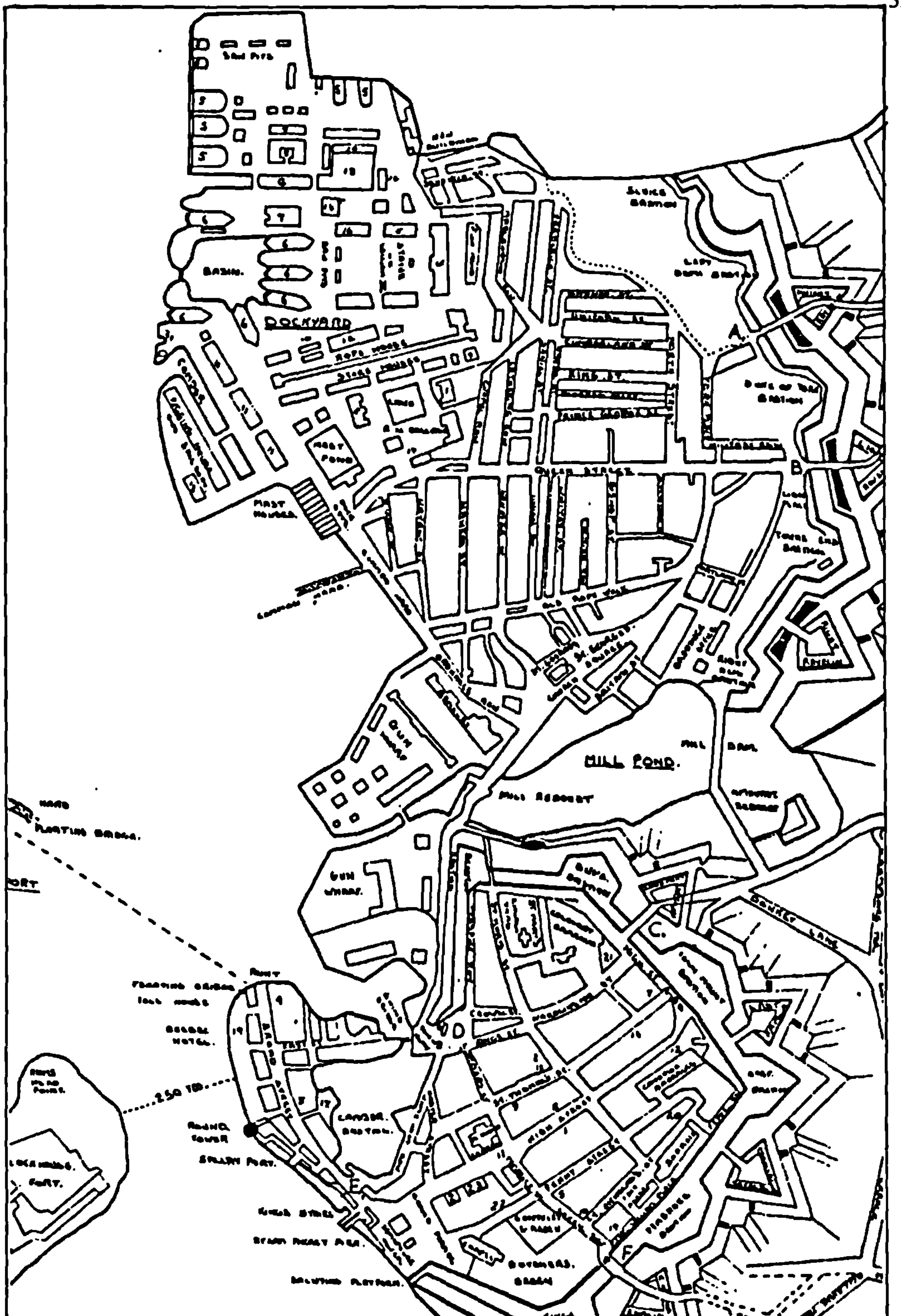
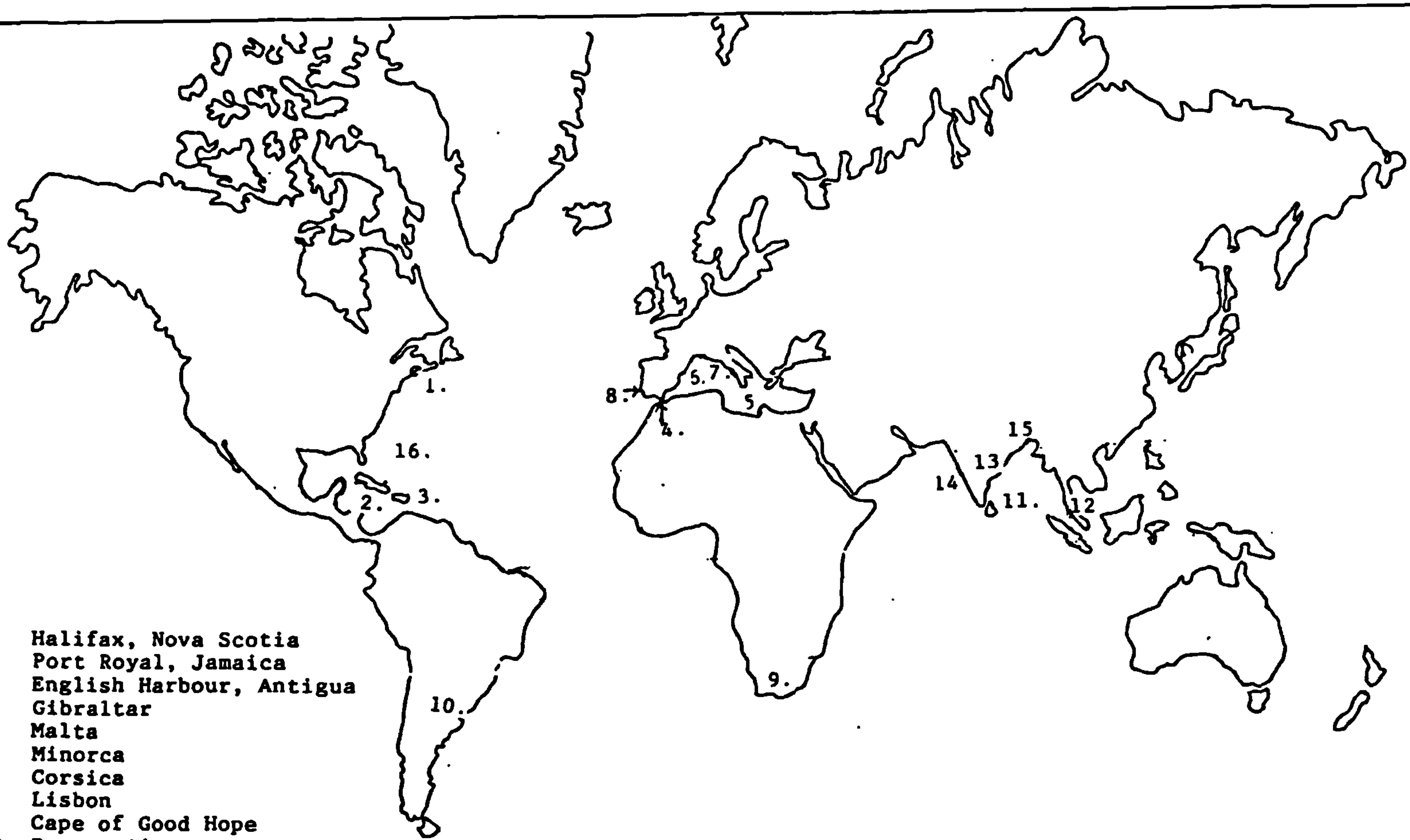


FIGURE 3.3 PORTSMOUTH TOWN

3.2.3. Overseas Bases and Dockyards: Wherever there was an important trading area overseas the Royal Navy tended to establish an Operational Area/Station within which ships were deployed, under a Commander in Chief whose task it was to operate those vessels as effectively as he could in the light of the circumstances he found confronting him. Invariably Commanders in Chief complained of having inadequate ships, usually in terms of numbers, types and material state, and being grossly under resourced in terms of Base and Dockyard facilities, for all the tasks placed upon them which, broadly speaking, were to protect British merchant ships in the area and to render aid to British colonists as and when it was needed. It was not unknown for naval officers to act in a quasi-diplomatic role and assist British traders in foreign ports in their negotiations with the local authorities - sometimes quite forcibly! As can be seen from the map (Figure 3.4), which shows the positions of the more important overseas dockyards and naval bases of the period, the Navy's support organisation covered, with the exception of the Pacific, virtually the world and its operation must have been a highly complex business.

3.3. The Tasks of The Royal Navy. Tasks undertaken by the Royal Navy to implement the Government's strategy for defence had implications for the dockyards in their responsibilities for support and maintenance of the Fleet. The most important task for the Navy was the defence of the realm, which involved fighting the enemy at sea in every size of conflict from minor skirmishes to major fleet engagements, and blockading enemy ports to prevent the invasion of Britain[10]. Blockading would also damage enemy trade and thus her ability to create wealth. A second equally important task was the defence of British trade and it was in the best interests of the Navy to support and protect a thriving merchant fleet since that was considered to be the Royal Navy's primary source of trained seamen[11]. A third, and perhaps under-rated task, was that of joint-operations with the British Army. As Britain is an island, her Army has to be transported to the areas of warfare and if necessary evacuated from them, and the Navy was able to provide additional support by its ability to land naval guns and men in support of the Army.



1. Halifax, Nova Scotia
2. Port Royal, Jamaica
3. English Harbour, Antigua
4. Gibraltar
5. Malta
6. Minorca
7. Corsica
8. Lisbon
9. Cape of Good Hope
10. Buenos Aires
11. Trincomalee
12. Penang
16. Bermuda

Property of the East India Company.

13. Madras
14. Bombay
15. Calcutta

FIGURE 3.4 OVERSEAS DOCKYARDS/BASES

The Navy interpreted the task of defence of the realm proactively and aimed to seek out and destroy the enemy. The destruction of the enemy's battle fleet would remove the risk of invasion and at the same time it would eliminate a major hazard to Britain's merchant shipping. However it was not French policy to seek major fleet engagements in the same way that the Royal Navy did. Rather than deliberately seeking out the enemy, the French fleet tended to make sorties from port for specific purposes, such as supporting the expedition to Ireland in December 1796 or the planned invasions of Britain in 1801 and 1805[12].

3.3.1. Fleet Engagements. When it was possible the classic battle tactic was to move the line of ships across the line of the approaching enemy; each ship fired a broadside as it crossed the enemy's line thus raking the length of the enemy ship, which could only reply with the two to four guns pointing ahead in the bows[13]. The most common scenario was when ships of both fleets in line, passed and repassed on opposite tacks and exchanged broadsides until the line was reduced to disorder, when the signal for a 'general chase' was given by the side whose line had not broken. Small engagements could be between two or three ships and range from a skirmish to a running battle over several days and many of these actions took place between frigates rather than ships-of-the-line.

Engagements large and small took place all over the world, but between 1793 and 1815, there were only five occasions on which the ships of the Royal Navy and those of France and her allies fought a major "Fleet" action (battle) at sea (see Figure 3.5.1). The last major fleet engagement on 21st October 1805, saw the destruction of the French and Spanish fleets off Cape Trafalgar[14]. A sixth major engagement fought by the Royal Navy was not against the French fleet but against the defences of the city of Copenhagen, which included the Trekronor shore battery and floating forts made from armed hulks.

3.3.2. Blockades: Blockading was the tactic used to keep the enemy fleet confined to their bases (Figure 3.5.2.). France and her principal ally Spain suffered from shortages of essential foodstuffs and raw materials as a result of the lack of protection available to their merchant ships due to the French and Spanish warships being blockaded into their harbours by the Royal Navy.

MAJOR FLEET BATTLES

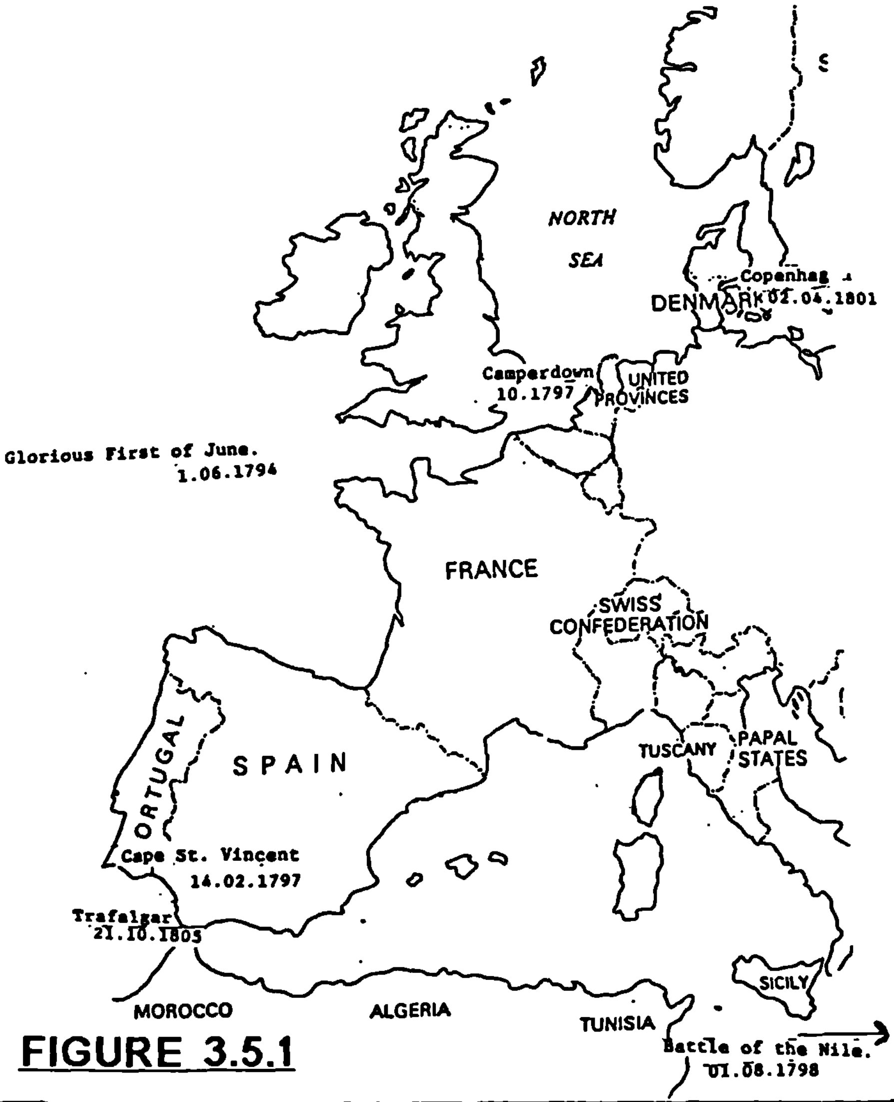


FIGURE 3.5.1

FRANCE:- 1. Brest
2. L'Orient
3. La Rochelle
4. Rochfort
5. Toulon

HOLLAND:- 10. Antwerp
11. Flushing
12. Amsterdam

SPAIN:- 6. Ferrol
7. Cadiz
8. Cartegena
9. Guarnizo

FRENCH/ALLIES NAVAL BASES

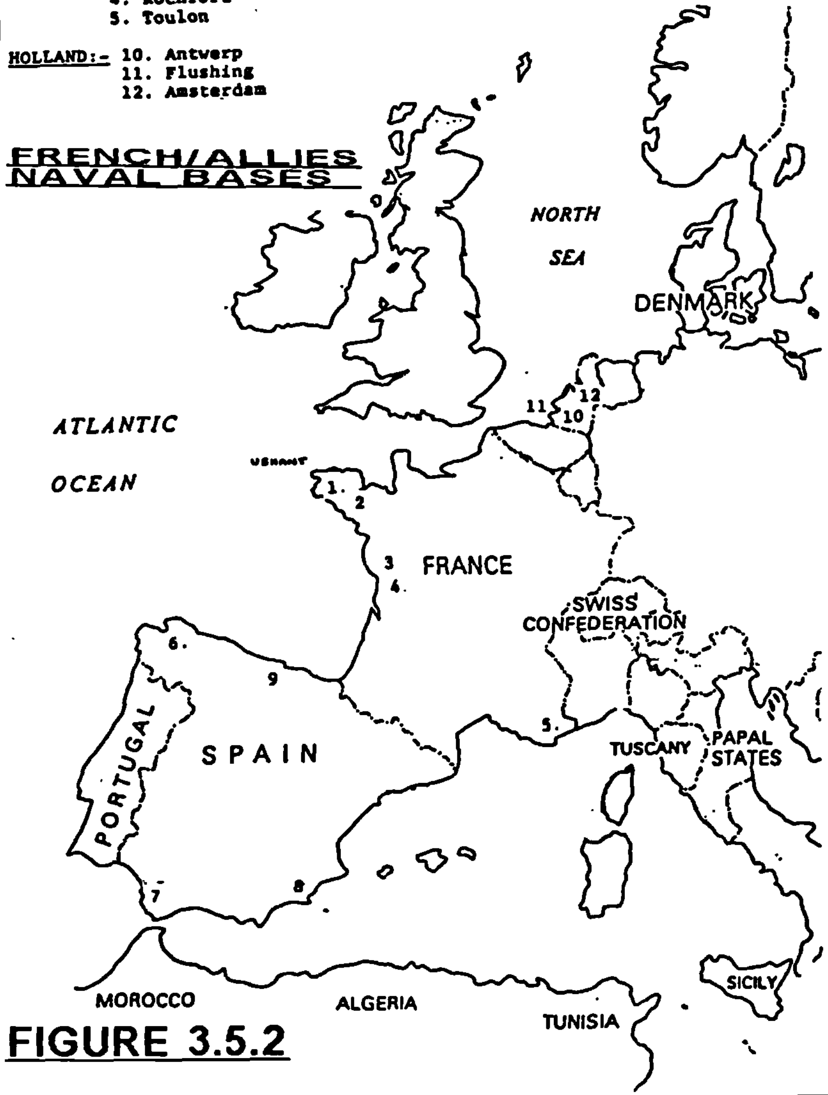


FIGURE 3.5.2

There were two types of blockade, the open and the closed. The open blockade consisted of using frigates to maintain a watch on the enemy ports while the main fleet was at sea during the summertime. In winter or in poor weather, the fleet went to an anchorage protected from westerly gales. However an open blockade, when the British fleet was not readily to hand, could allow the French fleet to slip out of harbour because weather conditions which hindered one side could be of advantage to the other, to prevent this eventuality a closed blockade system was used[15].

During the campaign of 1759, in the Seven Years War, the Western Squadron commanded by Sir Edward Hawke successfully maintained a close blockade of the French Atlantic ports[16] and this idea was revived by Admiral Earl St. Vincent from 1800[17]. Using frigates and other small ships to patrol close inshore and report any French fleet movements, the ships of the line remained out at sea but within easy reach of the blockaded ports regardless of the season or weather. When blockading the French ports of Brest, L'Orient, La Rochelle and Rochefort, (see Figure 3.5.2) the fleet lay off Ushant. Any necessary refitting and repairs needing a dockyard or naval base took place either at Plymouth or in Tor Bay and special permission from St. Vincent or the Admiralty was needed for ships to go to Portsmouth for docking. The Breton coast around Brest is rocky and exposed. So when the weather became too wild to allow the Fleet to maintain its station off Ushant it would run for cover in either Cawsands or Tor Bay whilst hoping that the severe conditions would deter the French fleet from attempting to put to sea[18].

Toulon, the major French port on the Mediterranean coast was also closely blockaded with the Royal Navy using the coast of Sardinia as a haven, and source of water[19], although from 1800, Malta was used as a stores base and dockyard although its distance from Toulon did present a major problem. In a letter of 1803 to Admiral Pasley, Nelson wrote "...Admiral Campbell was very well when we parted. He is gone to look for water in Sardinia; for Malta is such an immense distance that I can send nothing there that I may want under 6 or 7 weeks...."[20]

The shallower waters of the North Sea, although not subject to the long Atlantic swell, made blockade duty particularly arduous in winter when sleet, snow and frost were added to the problems facing naval operations. It fell to the North Sea Fleet to blockade the Dutch coast (see Figure 3.5.2) and keep the Dutch fleet incarcerated in the Texel. In

1797, at the time of the Nore mutiny, the Texel channel was blockaded by Admiral Duncan with just two ships[21].

3.3.3. Convoys: In the eighteenth and early nineteenth centuries Britain became increasingly bent on selling goods to world-wide markets and part of this trade paid for the Royal Navy which protected the merchant shipping. Trade could be divided into three elements, imports, exports and re-exports. Imports included raw materials like timber, iron, cotton and foodstuffs; particularly grain or produce which could not be grown in the British climate like sugar, tea and tobacco. Goods made in Britain such as woollens, cotton goods, cutlery and hardware were exported around the world. Re-exports were the produce of Britain's colonies like tea and sugar, which under the Navigation Laws were landed in Britain before re-export to another destination such as Continental Europe[22].

During successive wars against other maritime powers, the Royal Navy had evolved a two-pronged system for the protection of the merchant fleet at sea, by the use of convoys, and of patrolled areas. The idea of gathering a number of ships together into a convoy went back to medieval times; merchant ships gathered at an agreed port or anchorage and with a comparatively small number of armed escorts sailed together for their destination. Protection was gained from the numbers involved as large-scale destructive raids on convoys were exceptional. 'Hit and run' attacks by a single or small numbers of aggressors were the most likely. If a single aggressor came upon a convoy, even an unescorted one, it could only attack one ship at a time, so the rest had a reasonable chance of escape. The majority of losses occurred from the 'cutting out' of weak or slow ships or if a convoy became scattered in bad weather. Convoys sailed on well-ordered routes at regular intervals, often fortnightly, or monthly. The convoy escorts were drawn from the Navy's smaller ships, but ships of the line going to or returning from foreign stations would travel with a convoy to give it additional protection when the opportunity arose or when a convoy was particularly important - such as when a new Colonial Governor was taking passage within it.

The Royal Navy and Lloyds jointly organised the convoy system and the common practise of breaking away from a convoy early, as the port of arrival was approached, in order to gain an advantage over trading rivals[23] was effectively stopped when convoy breakers were subjected to heavy fines.

Some ships were exempt from the convoy system if they so wished and those of the East India Company and the Hudson Bay Company were sufficiently large and well armed to be able to defend themselves; as could some other fast and well-armed ships referred to as 'runners'[24]. Although the Royal Navy did arrange regular convoys for the coastal trade, including ships calling at Irish ports, there was no compulsion to join them as there was for the long distance traffic. As coastal traffic worked to very narrow time limits for deliveries, and the ships concerned visited many small ports, it was more practical for them to move singly rather than in convoys.

3.3.4. Patrolled Areas: Patrolled areas arose to protect convoys and single ships in places where the trade routes were heaviest and where ships were especially vulnerable to attack by the enemy's fleet or more particularly from privateers - for example in the Channel where a great number of routes converge particularly those for the Port of London. Patrolled areas were also used overseas close to terminal ports in the West Indies, around the coast of India and from 1808 to 1812 in the Baltic, when the hostile or neutral coast had extended to Denmark, Prussia and Scandinavia[25].

As the French Fleet became unable; and certainly unwilling, to continue to dispute control of the seas with Britain, French seamen resorted to the traditional strategy of the 'guerre de course' and "Privateering" became the main occupation of the French seafaring communities as her merchant fleet declined. Small, fast and heavily manned ships issuing from the French ports could attack British shipping and return swiftly to their home ports. Indeed they became sufficiently bold to take ships within sight of the British coast in daylight. As the French sphere of influence spread along the Northern European coast, so did the ports used by privateers, ranging from Brittany to Denmark and Norway[26] and a prime duty of patrolling ships was to destroy or capture these "nuisances".

Shipping in the Caribbean was likewise at risk where a Royal Naval presence was especially welcomed by the British colonists. So anxious were these British colonists in the Leeward and Windward Islands, to retain this protection against French and Spanish privateers operating from islands in the immediate area that the colonists on Antigua bought the site for a permanent naval base and presented it to the Navy[27]. In the Indian Ocean the island of Mauritius had served as a French privateering base for generations and its capture therefore diminished losses[28]. A joint venture by the East India Company and the Royal Navy secured Dutch bases in the East Indies in 1797 and prevented them falling into French hands which secured the safety of merchant vessels sailing to the Far East[29].

Anti-privateer work continued up to the end of the war against France. When the United States of America declared war against Britain in 1812, there were initially insufficient ships to reinforce the North American station due to the continuing war in Europe and American privateers from ports like Baltimore threatened British trade in the Caribbean and North Atlantic[30] but by the following year, 1813, the Royal Navy was able to blockade American naval and commercial ports and virtually brought the eastern seaboard trade to a standstill[31]. This only ceased with the signing of a peace treaty between Britain and the United States on 24th December 1814[32].

3.3.5. Joint Army/Navy Operations: The British Army needed the assistance of the Royal Navy in any of its ventures outside the United Kingdom and the Transport Board, subordinate to the Admiralty, arranged the ships which carried men, horses, equipment and supplies for the Army. In the European theatre of war, British military expeditions were small-scale compared to those of our allies who could put major armies in the field. Nevertheless, considering they involved a landing from the sea, and all too frequently, a hasty withdrawal back across it, they were substantial joint service operations. 1809 started with the withdrawal of the 26,000 survivors of Sir John Moore's force of 35,000 from Corunna in January. For this operation about 200 transports and 12 ships of the line were assembled[33] and in September, troops, ordnance and stores involved in the abortive Walcheren landing on the Dutch coast were safely withdrawn by sea[34].

Not all landings were unsuccessful. The raid on Helder in 1799[35], captured the port, naval base and Dutch fleet, many of which were added to the British fleet, and that by the Royal Navy and 25,000 troops on Copenhagen in 1807 captured 15 Danish ships-of-the-line[36]. This successful joint-operation prevented Napoleon from combining the fleets of Denmark, Sweden, Russia and Holland which would have posed a considerable threat to the realm and the Royal Navy, as well as seriously endangering the vital supply of naval stores from the Baltic which were so important the Navy.

Wellington's Peninsular campaigns are arguably one of the finest examples of British joint naval-military operations. The Army's demands for manpower and stores were enormous since all its requirements had to be purchased, transported to Portugal and then moved over land to where they were needed. Through the war the Army's strength progressively increased until over 80,000 British and allied Portuguese and Spanish troops were armed, fed and maintained by Britain. This posed major problems for the Navy in terms of protected sea-borne transport and its organization into convoys which sailed monthly from Britain for Lisbon and Oporto[37]. However in 1813 Wellington was able to shorten his land supply lines by moving his ports of supply from Lisbon and Oporto to Santander and Bilbao. On top of the convoy shipping Wellington had felt compelled in 1810-1811 to persuade the British Government to maintain transports in the River Tagus so that in the event of a heavy reinforcement of French troops, the British Army, having withdrawn to the Lines of Torres Vedras, could be safely evacuated but the maintenance of these ships and their crews was an additional, and sustained, demand on the Navy's resources. Lastly, the Navy played its part in enabling diversionary landings and guerilla raids along the Spanish coast behind the French lines. For example, during the protracted seige of Cadiz by the French from February 1810 to August 1812, as well as British ships supplying the city from the sea, naval personnel assisted the Spanish in manning floating batteries[38].

Joint operations took place world-wide, with the Army and Navy working together in expeditions to capture or eliminate privateering bases in the Caribbean, Indian Ocean and East Indies. The expeditions to capture the Dutch base at the Cape of Good Hope in 1795, and that against Buenos Aires in 1806 and 1807 which was mounted from the Cape of Good Hope were good examples. Indeed that against Buenos Aires was planned and executed without Governmental approval, although politicians were quick to see the trading advantages while deploring the expedition[39]. The capture of the last French Caribbean island in February 1810[40] not only increased the flow of British Trade in that part of the world but also allowed British garrisons to be released for service elsewhere. By 1810 Senegal, Cayenne, the Seychelles, the Isle de Bourbon[41], Amboina[42] and Banda Neira[43] had all fallen to British expeditions and the foundations of a new Commonwealth in the Far East had been laid with the establishment of Sydney.

Just as the Army needed the Royal Navy for transportation and protection, so the Navy needed the Army. Naval bases overseas, especially those in the Mediterranean and West Indies, had permanent military garrisons to protect the naval installations and harbour from attack by France or her allies. At Earl St. Vincent's suggestion, the victualling base on Gibraltar was re-sited so that not only did it have an enlarged capacity, but it was no longer in the reach of artillery on mainland Spain[44].

3.4. Types of Ships in The Fleet. The tasks which the Royal Navy undertook on behalf of the Government dictated the size and shape of the fleet which in 1793 consisted of 411 vessels which could roughly be divided into three broad types, within which there were different ship classes with differing roles. The three broad types were capital ships, cruisers and minor warships.

3.4.1. Capital Ships: The task of engaging and destroying the enemy was the role of the capital ships of eighteenth century which were called "Line of Battle" ships or more often "Ships of the Line". They carried 60 to 100 guns on either two or three gundecks depending on the size of the ship. To carry this weight of big guns they had to be both strong and large as well as capable of accommodating the large crew necessary to man them. The largest of the ships of the line were used as flagships, and with their large and imposing presence, were suitable for diplomatic missions when Britain's prestige and standing needed to be displayed. Ships of the line were required to be capable of withstanding the pounding of enemy guns in a line of battle engagement or from a shore bombardment while maintaining their own ability to engage the enemy regardless of their own state of damage. Their role of engaging enemy ships took precedence over blockade or convoying duties.

3.4.2. Cruisers: The cruisers of this period, like those of today, were the Frigates which carried from 20 to 50 guns on one gundeck and were used as fleet escorts as well as for patrolling, blockading and convoy protection duties where their firepower, good sailing qualities and ability to be away from a shore base for at least six months at a time, made them so invaluable. To quote a traditional Naval saying, famously used by "Jackie" Fisher[45] ..... they were faster than anything bigger and bigger than anything faster.

When frigates were in company with a fleet of ships of the line, they acted as scouts, working ahead of the main formation and reporting sightings of enemy vessels. Although frigates were not considered to be a real opponent for a ship of the line with its superior firepower, it was by no means uncommon for Royal Naval frigates to engage in single ship combat with a French or Spanish Line of Battle ship. On these occasions the frigate's best tactic was to exploit its greater agility to keep out of as much harm as possible whilst attacking the enemy's vulnerable stern. On 28th February 1797 the 32 gun Terpsichore fought the 120 gun Santissima Trinidad off Cape Spartel on the Moroccan coast and survived.[46]

Frigates were also widely used also for patrolling the shipping lanes and protecting merchant shipping from attacks by enemy warships and privateers. At the same time they looked to capture the enemy warships and merchant ships whenever possible. On blockade duties, frigates were able to operate closer inshore than the bigger and deeper ships of the line and, with their superior sailing abilities, they could gather intelligence by approaching enemy harbours to see what was there. If the circumstances were right they were also quick to seize the opportunity to cut out enemy ships as prizes. Lastly, Frigates, were used to support combined operations with the Army, including special missions like coastal guerilla raids. Their combination of speed, fire power and a considerable number of boats made them a natural choice for this type of operation.

3.4.3. Minor War Vessels: Within this heading were a range of different classes of vessels, the largest of which were the sloops carrying from 14 to 18 guns. Like the frigates they could work as information gatherers but their small size and shallow draught allowed them to work even closer into the coast. As well as collecting intelligence, sloops carried dispatches, letters, orders, stores and people. As such they were a vital communication link between the Admiralty and the overseas stations as well as within the areas covered by those stations. Sloops also took their part in blockade duties, protecting convoys and the search for and destruction of privateers.

Among the other classes there were two specialist ones - the Fireships and Bombs. Fireships were a traditional naval weapon of war for destroying enemy ships in harbour. Bombs were used exclusively for shore bombardments (including harbours) - they had no place in sea battles. They had a mortar resting on a platform in the centre of the vessel, and a specially strengthened hull to withstand the recoil of a projectile weighing up to 195 pounds which could be fired to a range of 4,000 yards. The really significant thing about them was that the flight of the projectile was very much "up and over" and therefore they could attack targets hidden behind fortifications whilst themselves being outside the range of the conventional guns of the period.

3.5. Fleet Size. As the war progressed so did the total number of ships in the Royal Navy. Figures 3.6 and 3.6.1, together with Table 3.1[47], show that from a low of 390 in 1793 it reached a peak of 979 in 1809. However by no means all ships were available for sea service at any one time as can be seen, in percentage terms, in Figure 3.6.2. In addition to those ships which were in the operational sea going fleet there were some held in reserve for operational service, some used only for service in harbour and even a number held in reserve for harbour service - Table 3.1.1 shows the spread of these statuses for the period 1793 - 1816 and this is illustrated in Figures 3.6.3 and 3.6.4 respectively for the Line of Battle and Frigates and below. However, whether ships were operational or not they all had to be maintained - albeit at differing levels of readiness and periodicity.

3.6. Fleet Losses. Frequent mention has been made in this chapter of "weather", "operating close in shore" etc and collectively these are all part of the Navy's primary battle which was the constant struggle by its ships to survive in the face of the maritime environment. During the course of the French wars, the Royal Navy lost 482 ships of all classes and sizes[48]. Of the 482 ships lost between February 1793 and July 1815, 125 were captured, 16 were destroyed in action and of the rest, 251 were wrecked, 75 foundered[49] and the remaining 15 were lost due to fire.[50] Figure 3.7, supported by Table 3.2 , shows the Navy's year on year losses due to these causes across the period. For those who have been brought up to believe that the Royal Navy was largely invincible during the Napoleonic war these figures may come as something of a surprise. However little further thought is needed to realise that if the environment caused so many ships to be wrecked or founder then how much larger must have been the number of ships requiring **unprogrammed** repair and maintenance work to make good the beating they were continually taking from the elements. It is certainly a fair deduction that the Royal Navy's main contest across the period was against the weather rather than against the ships of the enemy. This leads in turn to the conclusion that the Dockyard managers were inevitably operating, for much of the time, in a short term, or crisis, mode.

TABLE 3.1

1790 - 1802. FLEET COMPOSITION

FLEET COMP.		1790	1791	1792	1793	1794	1795	1796	1797	1798	1799	1800	1801	1802
A	1ST Rates				5	6	6	6	7	8	8	9	8	8
B	2nd Rates				19	19	20	19	19	20	21	19	19	19
C	3 & 4th				136	139	140	147	145	155	160	162	165	164
E	5th Rates				90	94	112	118	130	135	132	132	134	141
F	6th Rates				41	42	41	44	47	49	51	47	47	44
G	Minor V.				99	120	164	200	239	293	322	360	362	370
FLEET TOTALS					390	420	483	534	587	660	694	729	735	746

TABLE 3.1A

754

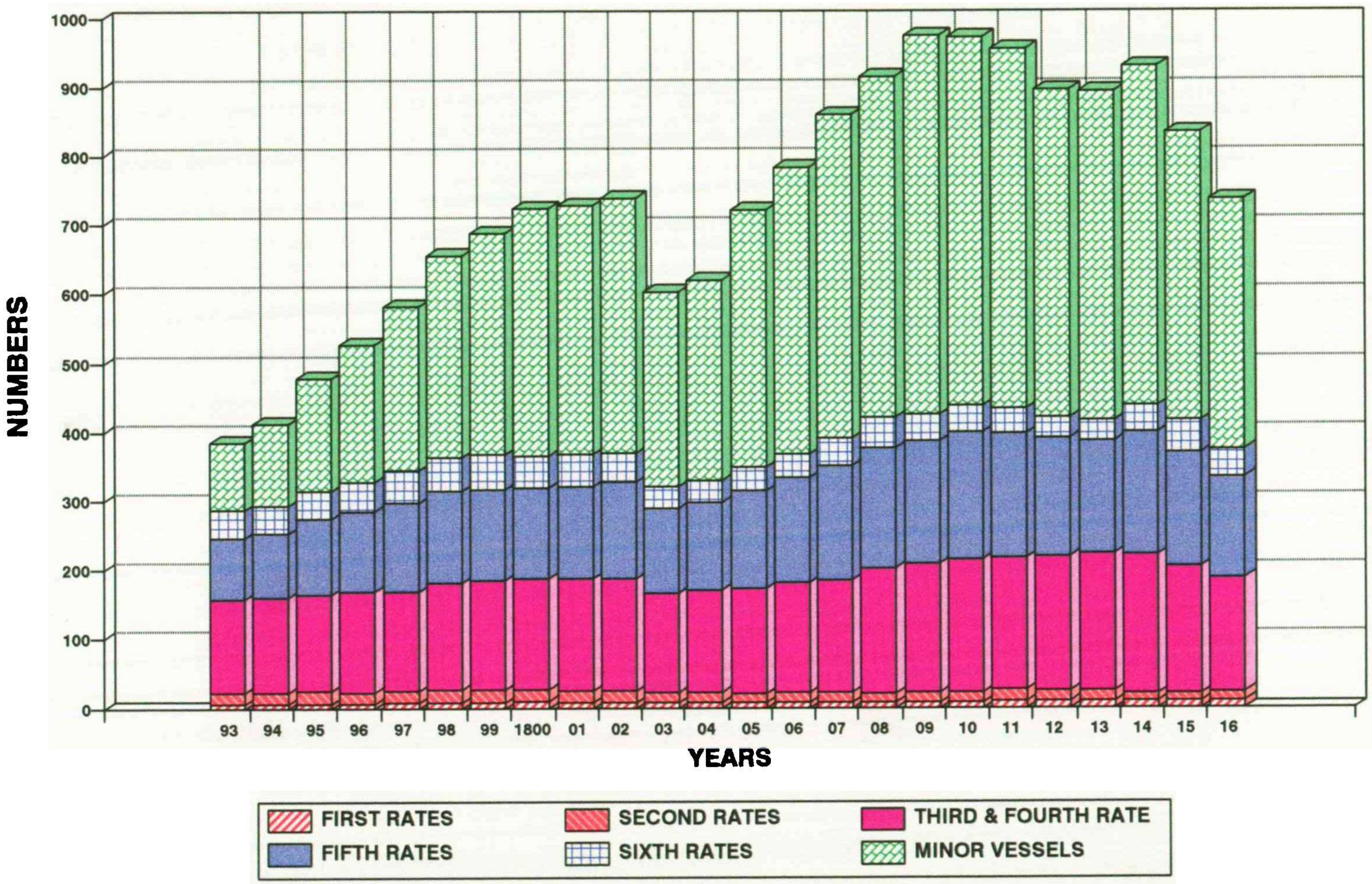
1803 - 1816. FLEET COMPOSITION

FLEET COMP.		1803	1804	1805	1806	1807	1808	1809	1810	1811	1812	1813	1814	1815	1816
A	1ST Rates	7	7	8	8	8	8	8	8	9	9	9	9	10	9
B	2nd Rates	15	15	14	15	15	14	15	15	17	15	16	12	12	14
C	3 & 4th	146	149	154	161	165	184	188	194	192	195	201	202	186	167
E	5th Rates	124	128	142	153	166	175	179	185	181	173	165	180	167	147
F	6th Rates	33	33	34	36	41	46	40	40	38	30	31	40	47	42
G	Minor V.	283	291	374	416	470	494	549	534	523	476	477	493	419	364
FLEET TOTALS		608	623	726	789	865	921	979	976	960	898	899	936	841	743

TABLE 3.1B

FIGURE 3.6

COMPOSITION OF THE FLEET
BY CLASSES



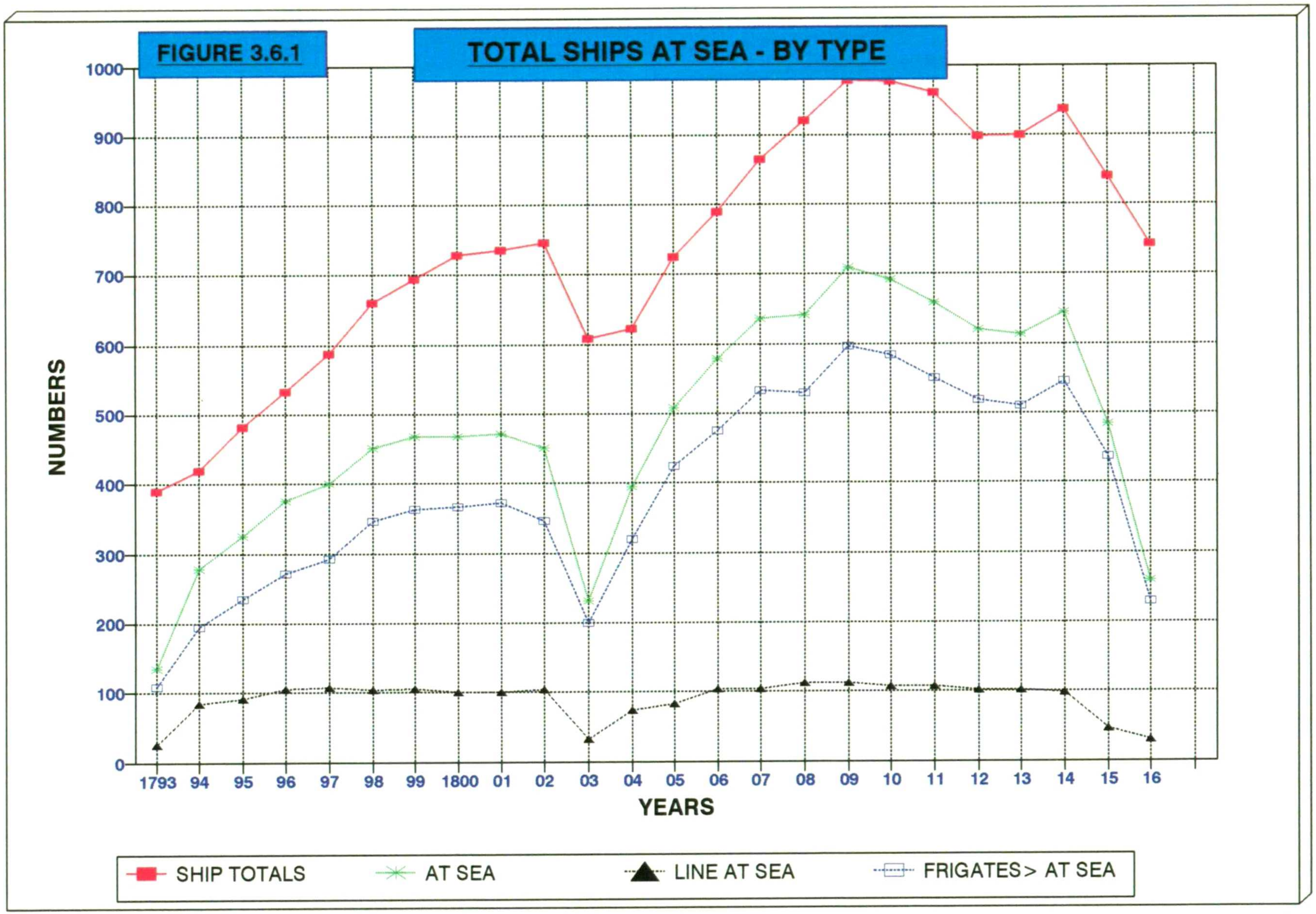


FIGURE 3.6.1
TOTAL SHIPS AT SEA - BY TYPE
NUMBERS
1000
900
800
700
600
500
400
300
200
100
0
1793 94 95 96 97 98 99 1800 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16
YEARS
SHIP TOTALS
AT SEA
LINE AT SEA
FRIGATES> AT SEA

TABLE 3.1.1 - FLEET's OPERATIONAL STATUS

YEAR	TOTAL NUMBER OF SHIPS IN FLEET	TOTAL NUMBER IN COMMISSION AT SEA	TOTAL % AT SEA	LINE AT SEA	LINE HARBOUR SERVICE	LINE IN ORD FOR SEA	LINE IN ORD FOR HBR	S.T.LINE NOT AT SEA	% LINE AT SEA	FF & > AT SEA	FF & > HARBOUR SERVICE	FF & > IN ORD FOR SEA	FF & > IN ORD FOR HBR	S.T.FF & > NOT AT SEA	% FF & > AT SEA
1793	390	135	35	28	3	87	25	115	18	109	11	82	47	140	44
94	420	279	66	85	6	32	22	60	59	194	26	17	38	81	71
95	483	326	67	91	10	23	20	53	63	235	59	14	31	104	69
96	534	376	70	105	10	11	20	41	72	271	60	16	39	117	70
97	587	401	68	108	15	8	19	42	72	293	65	26	53	144	67
98	660	451	68	104	21	16	21	58	64	347	64	35	51	150	70
99	694	469	68	105	33	20	12	65	62	364	82	28	50	160	69
1800	729	468	64	100	30	24	14	68	60	368	101	18	74	193	66
01	735	472	64	100	21	27	22	70	59	372	113	12	68	193	66
02	746	451	60	104	17	22	26	65	62	347	111	32	87	230	60
03	608	232	38	32		79	39	118	21	200	10	131	117	258	44
04	623	395	63	75	9	40	29	78	49	320	36	39	74	149	68
05	726	508	70	83	11	33	28	72	54	425	34	36	76	146	74
06	789	579	73	104	17	16	27	60	63	475	38	30	81	149	76
07	865	636	74	103	20	20	27	67	61	533	38	34	90	162	77
08	921	642	70	113	19	13	44	76	60	529	34	46	123	203	72
09	979	709	72	113	28	14	40	82	58	596	36	32	120	188	76
10	976	692	71	108	35	16	42	93	54	584	37	21	133	191	75
11	960	658	69	107	38	17	42	97	52	551	31	21	153	205	73
12	898	621	69	102	40	18	46	104	50	519	31	22	120	173	75
13	899	613	68	102	41	22	50	113	47	511	31	18	124	173	75
14	936	644	69	99	39	19	47	105	49	545	30	24	133	187	74
15	841	485	58	47	11	62	71	144	25	438	24	53	135	212	67
16	743	260	35	30	3	70	70	143	17	230	15	135	190	340	40

NOTES: 1. LINE = 1ST, 2ND, 3RD & 4TH RATES (2 & 3 DECKS)

47a

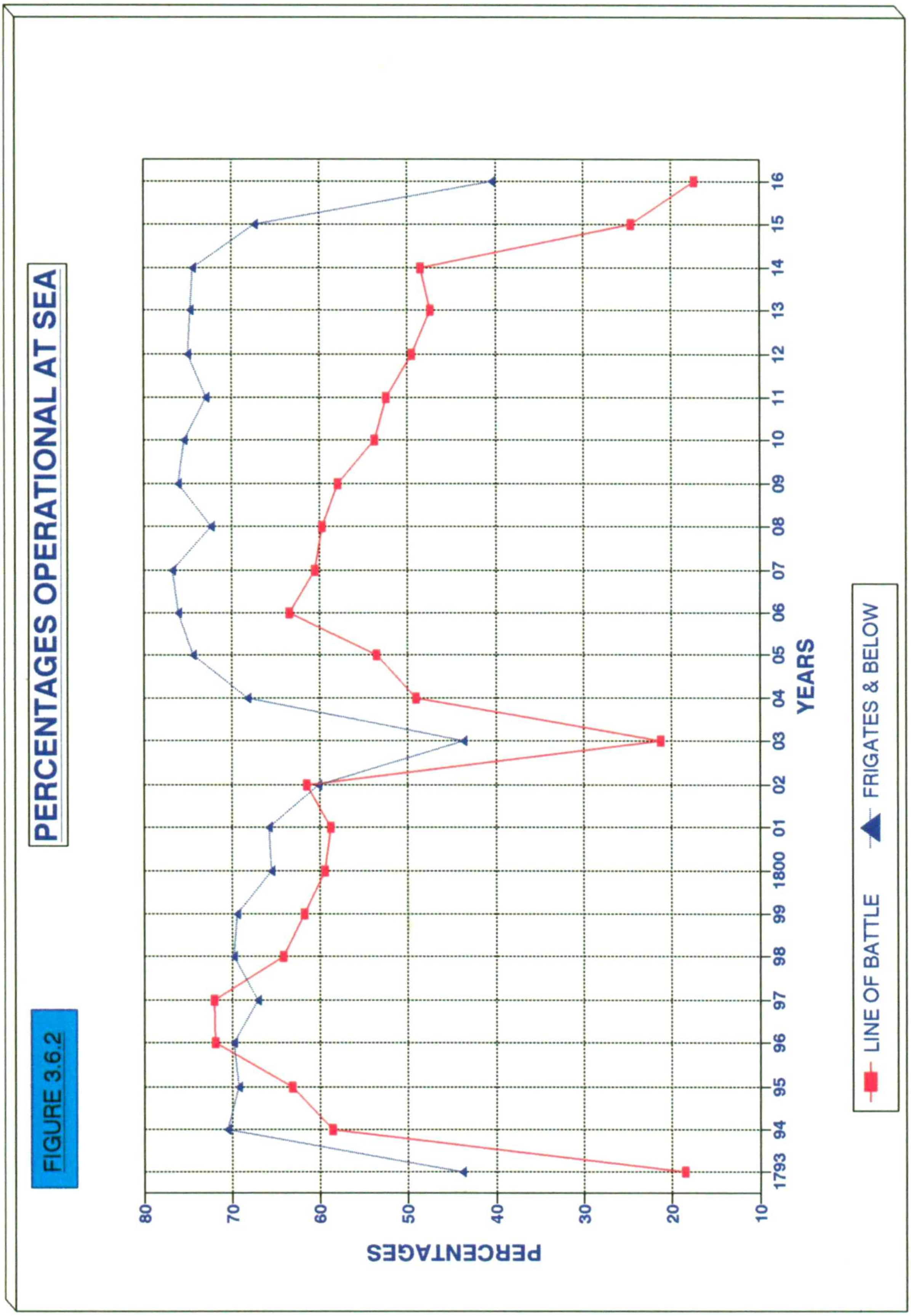
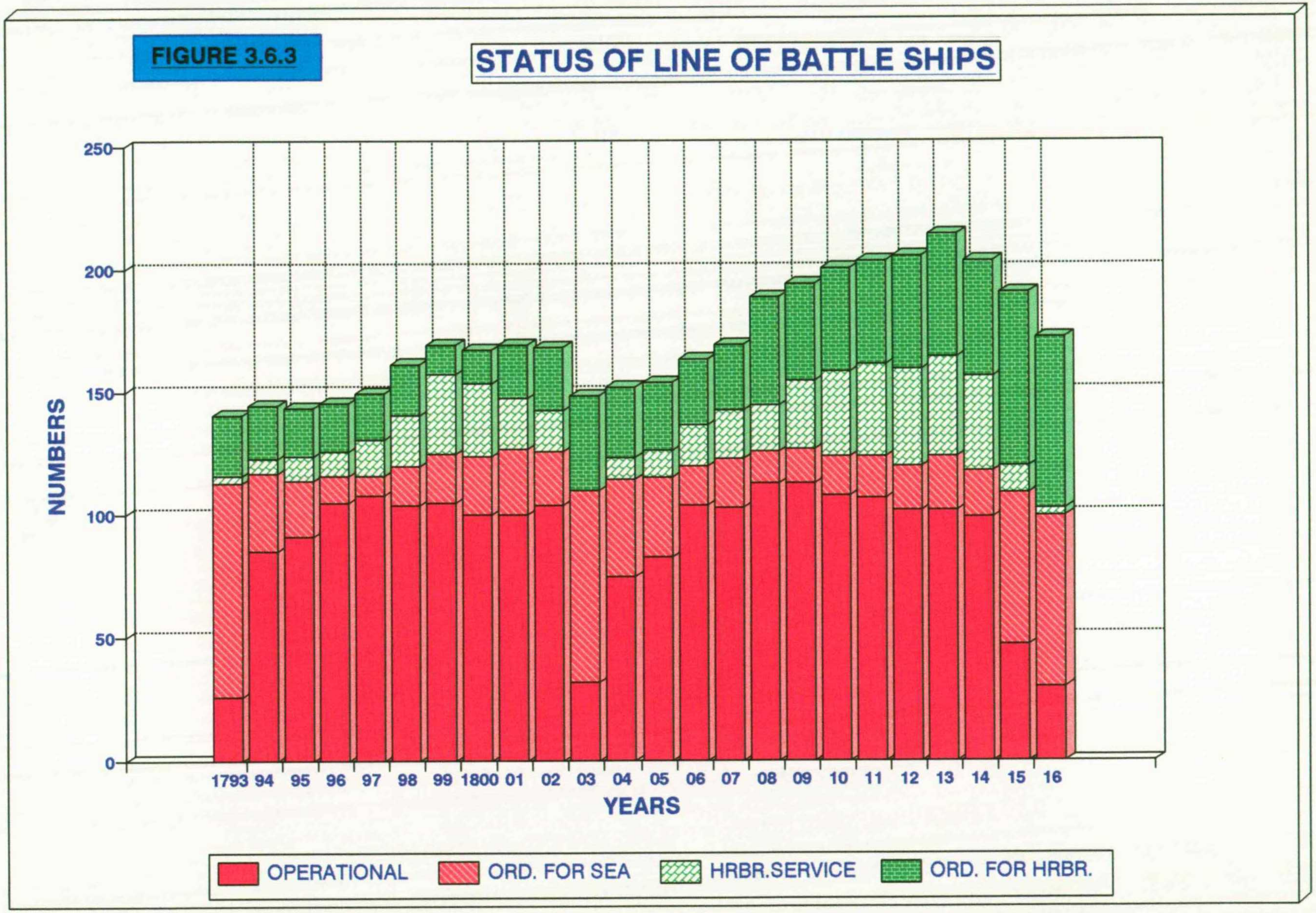


FIGURE 3.6.2
PERCENTAGES OPERATIONAL AT SEA
PERCENTAGES
80
70
60
50
40
30
20
10
1793
94
95
96
97
98
99
1800
01
02
03
04
05
06
07
08
09
10
11
12
13
14
15
16
YEARS
LINE OF BATTLE
FRIGATES & BELOW

FIGURE 3.6.3


STATUS OF LINE OF BATTLE SHIPS
NUMBERS
250
200
150
100
50
0
1793 94 95 96 97 98 99 1800 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16
YEARS
OPERATIONAL
ORD. FOR SEA
HRBR.SERVICE
ORD. FOR HRBR.

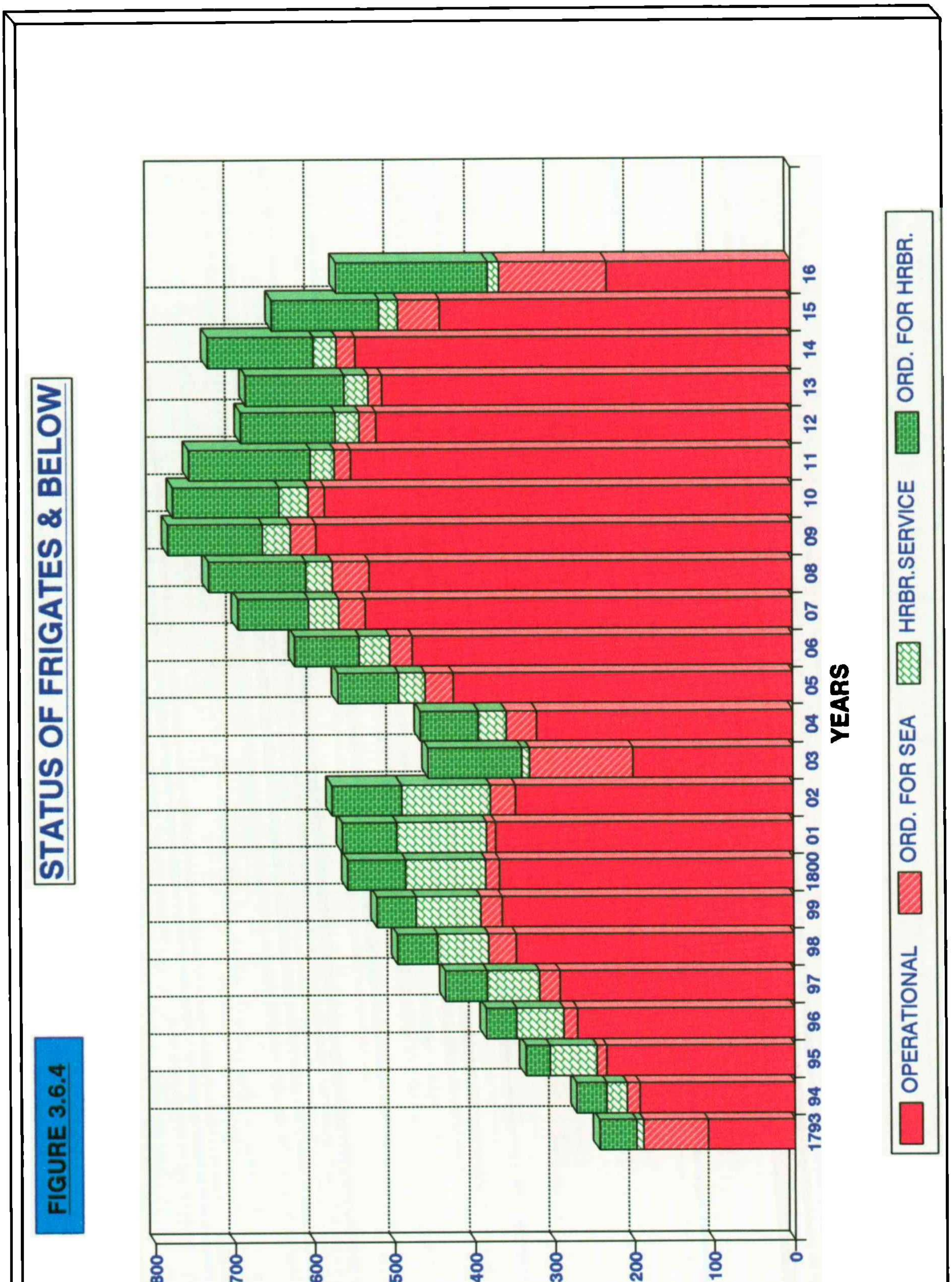


FIGURE 3.6.4
STATUS OF FRIGATES & BELOW
NUMBERS
0
100
200
300
400
500
600
700
800
YEARS
1793 94 95 96 97 98 99 1800 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16
OPERATIONAL
ORD. FOR SEA
HRBR.SERVICE
ORD. FOR HRBR.

TABLE 3.2 - RN SHIP LOSSES

YEAR	CAPTURED BY FRENCH	DESTROYED IN ACTION	WRECKED (SHORE)	FOUNDERED (SANK AT SEA)	BURNT	TOTAL
1793	4	2	3		1	10
1794	9	1	4	2	2	18
1795	6		5		1	12
1796	1		13	6	3	23
1797	4	1	8	5		18
1798	5		12	2	1	20
1799	3	1	16	1		21
1800	2	4	11	4	1	22
1801	8		10	2	1	21
1802			2	2		4
1803	3		9	2		14
1804	5		16	2	1	24
1805	10		11	5		26
1806	8		4	8	1	21
1807	9		21	8	1	39
1808	9	2	22	1		34
1809	6	1	18	6	1	32
1810	3		12	2		17
1811	7		16	2		25
1812	8		14	4		26
1813	5	2	11	3	1	22
1814	6	2	8	7		23
1815	4		5	1		10
TOTALS	125	16	251	75	15	482

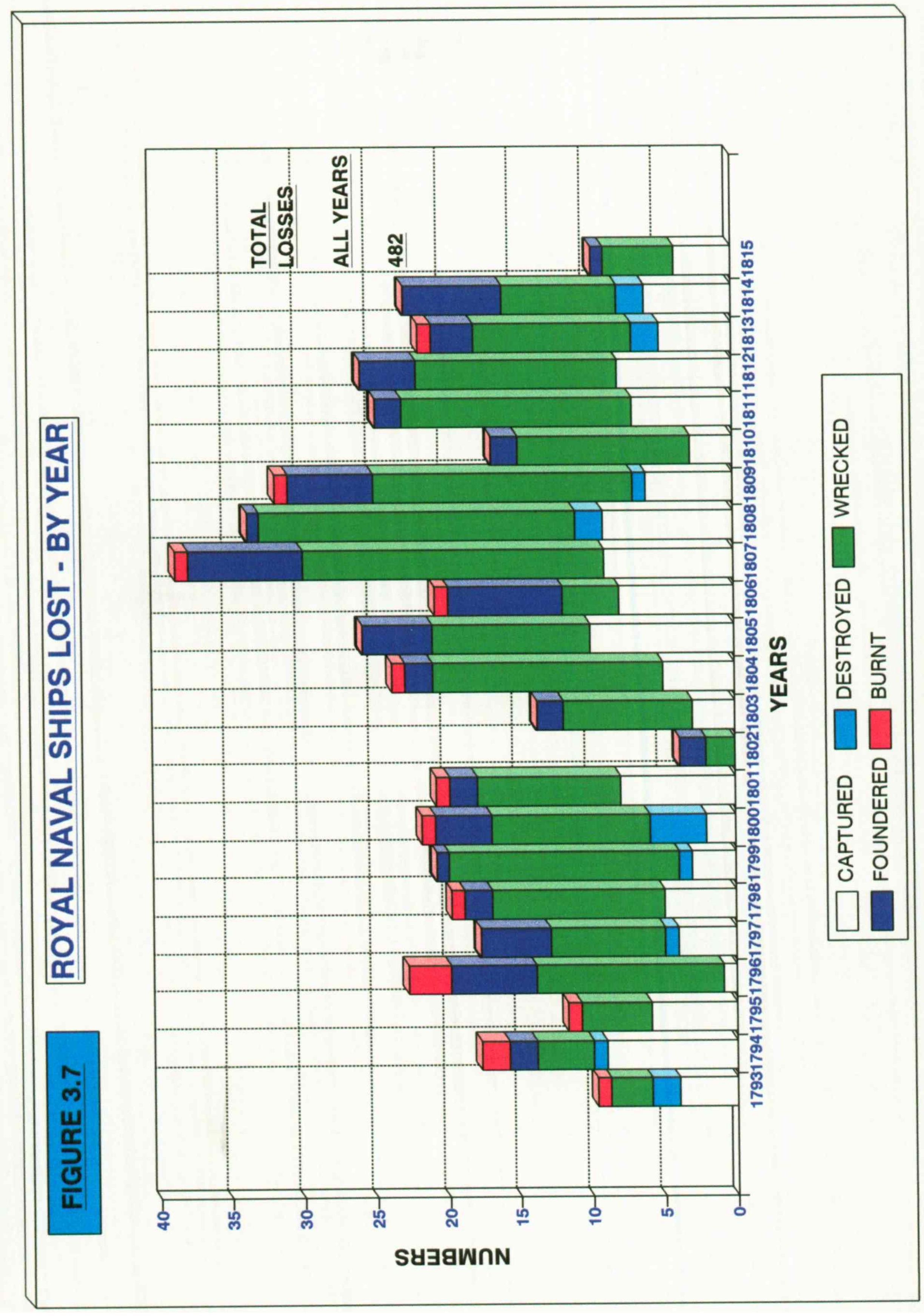


FIGURE 3.7
ROYAL NAVAL SHIPS LOST - BY YEAR
TOTAL LOSSES
ALL YEARS
482
NUMBERS
0
5
10
15
20
25
30
35
40
1793
1794
1795
1796
1797
1798
1799
1800
1801
1802
1803
1804
1805
1806
1807
1808
1809
1810
1811
1812
1813
1814
1815
YEARS
CAPTURED
DESTROYED
WRECKED
FOUNDERED
BURNT

1. Judith Blow Williams, *British Commercial Policy and Trade Expansion 1750-1850*, Oxford University Press, London, 1972, pages 427-433.

2. Jonathan Coad, *The Royal Dockyards 1690-1850*, Scolar Press, Aldershot, 1989, page 2.

3. Roger Morriss, *The Royal Dockyards during the Revolutionary and Napoleonic Wars*, Leicester University Press, Leicester, 1983, pages 3-5.

4. Ibid., p.143.

5. The Nore is a sandbank between Shoeburyness and Sheerness.

6. Morriss, op. cit. n.3, p.2.

7. ADM/140/555/14 to 18, Maps of Portsmouth Dockyard dated 1790,1793, 1796, Unknown and 1810.

8. Map of Old Portsmouth and the Dockyard, c. 1835, Local Maps Collection No 5382, Portsmouth Library.

9. Coad, op. cit. n.2, p.257.

10. Paul Kennedy, *The Rise and Fall of British Naval Mastery*, Fontana Press, London, 1991, 3rd edition, pages 146-147.

11. C.P.Hill, *British Economic and Social History 1700-1982*, Edward Arnold, Bath, 1985, 5th edition, page 61.

12. Brian Lavery, *Nelson's Navy, the ships, men and organization 1793-1815*, Conway Maritime Press, London, 1989, pages 295-300.

13. James Henderson, *The Frigates*, Adlard Coles, London, 1970, page 23.

14. Kennedy, op. cit. n.10, pp.146-147..

15. G.J.Marcus, *A Naval History of England - The age of Nelson*, Allen and Unwin, London, 1971, page 153.

16. Details of this campaign can be found in G.J.Marcus *Quiberon Bay, the campaign in home waters, 1759*, Hollis and Carter, London, 1960.

17. Marcus, op. cit. n.15, p.153.

18. Lavery, op. cit. n.12, p.280.

19. Ibid., p.280.

20. Sir N.H.Nicholas G.C.M.G. (ed), *The Despatches and Letters of Vice Admiral Lord Viscount Nelson*, London, 1855, Volume 5, page 244.

21. Marcus, op. cit., n.15, p.154.

22. Hill, op. cit. n.11, p.154.

23. Kennedy, op. cit. n.10, p.155.

24. Ibid., p.156.

25. Marcus, op. cit. n.15, pp.107-108.

26. Ibid., p.370.

27. Coad, op. cit. n.2, pp.355-360.

28. W. Laird Clowes, *The Royal Navy, a history from the Earliest Times to 1900*, William Clowes, London, 1900, Volume 5, pages 293-295.

29. Ibid., pp.290-293.

30. Marcus, op. cit. n.15, p.453.

31. Laird Clowes, op. cit. n.28, pp.63-65.

32. Ian R. Christie, *Wars and Revolutions, Britain 1760-1815*, The New History of England, Edward Arnold, London, 1982, Volume 7, pages 319-320.

33. Christopher Hall, 'The Royal Navy and the Peninsular War', *The Mariner's Mirror*, (1993), 79, pp. 409-410.

34. Despatches from Rear Admiral Otway, Commodore Owen and Lieutenant General Don, *Naval Chronicle*, Joyce Gold, London, 1809, Volume XXII, pages 77-84.

35. Christie, op. cit. n.32, p.248.

36. Ibid., p.307.

37. Hall, op. cit. n.33, pp.404-407.

38. Ibid., p.413.

39. John D.Grainger, 'The Navy in the River Plate 1806-1808', *The Mariner's Mirror*, (1995), 81, pp. 287-299.

40. Despatches relating to the capture of Guadeloupe, op. cit. n.34, v.XXIII, pp.339-345.

41. Despatches relating to the capture of Isle de Bourbon, op. cit. n.34, v.XXIV, pp.426-431.

42. Despatches relating to the expedition to Amboina and conditions for the Dutch surrender, Ibid., pp.335-343.

43. Laird Clowes, op. cit. n.28, v.5, pp.292-293.

44. Coad, op. cit. n.2, pp.316-317.

45. Admiral of the Fleet Sir John Arbuthnot (Jackie) Fisher GCB,OM,GCVO was First Sea Lord from 1904 to 1910. Undoubtedly the expression was made famous by his use of it but it may well have originated earlier in the context of frigates. Regrettably the available evidence does not support a definitive attribution.

46. Lieutenant Commander R.E.A. Shrubb, Royal Navy and Captain A.B. Sainsbury, VRD, Royal Naval Reserve, (eds), *The Royal Navy day by day*, Centaur Press, London, 1979, page 52.

47. William James, *The Naval History of Great Britain*, edited by Captain Chamier Royal Navy, Richard Bentley, London, 1847, 6 volumes, Abstracts of ships and vessels belonging to the Royal Navy, Nos 1 to 25 from 1793 to 1817.

48. Ibid., Information taken from tables of losses in Volumes 1-6.

49. Foundering- to sink at sea, as being rendered by the violence and continuation of a storm and the excess of leaks, unable to keep the ship afloat above the water. William Falconer's *Marine Dictionary*. T. Cadell, London 1769.

50. James, op. cit. n.47, v.6, p.507, Abstract No. 17.

CHAPTER FOUR
THE FLEET - MAINTENANCE OF ITS SHIPS BY PORTSMOUTH DOCKYARD

4.1 General. The previous Chapters on Politics and Maritime Activities discussed the policies and imperatives which generated the requirement for, and operation of, the Fleet and the different ship types. This Chapter examines the individual ship classes (more than one class made up a type) in material terms and thereafter it examines, in the detail relevant to this thesis, the generic nature of the construction of those vessels before moving on to discuss, and then enumerate, Portsmouth Dockyard's contribution to keeping those warships at sea. That enumeration leads to an analysis of Portsmouth Dockyard's output since it is against that output that the value of introducing new technology into the Dockyard must ultimately be judged. It must be borne in mind however that the nature of the Dockyard's output had to respond to the political, financial and strategic imperatives of the period as well as to the state of the ships both at the start of the period and throughout it. This state varied as the wear levels on the ships changed with the changing pattern of their operational utilisation. Furthermore there was a very considerable variation in the standards of the ships at the time they joined the fleet. Some were built in Royal Dockyards, others in commercial yards under contract and yet others came from continental dockyards having been captured and then "bought in" to the Royal Navy.

In 1783, the Admiralty Board estimated that the Royal Navy needed about 100 ships of the line and about twice this number of frigates to be available at all times, some in commission at sea and the rest in a state of readiness from which they could be got to sea as quickly as possible. It was accepted that a shortage of seamen to man the ships was more likely to delay the deployment of ships at sea rather than dilatoriness on the part of the dockyards, which in the case of ships of the line, repaired about 10 ships per year[1] between 1783 and 1793. However this was at the expense of the frigates and when these were urgently needed, work on ships of the line had to stop in order to work on the frigates. As it turned out, at the declaration of the Revolutionary War in 1793, the Royal Navy was in a good state of repair with 113 ships of the line and 126 frigates either at sea or in Ordinary[2], in addition there were about 65 smaller ships, mainly sloops and brigs.

Subsequently, as Table 3.1.1 showed, the number of ships in commission rose steadily throughout the war apart from a dip in the years 1803 and 1804 to a peak of 709 (out of a total of 979) in 1809 before beginning to decline towards the end of the war. - Details of the total numbers of ships the Navy had at any one time was shown in the previous Chapter in Figure 3.6 and Table 3.1.

4.2 Ship Classes. By the middle of the seventeenth century all British warships were classified under a rating system which was related to the number of guns carried. From the 1680's the rates were in six divisions and the numbers of guns within each rate were revised in 1716, 1740, 1757 and 1790[3]. The figures for the years 1790 to 1817 are shown below[4],

First Rate	100 to 120 guns
Second Rate	90 to 98 guns
Third Rate	64 to 80 guns
Fourth Rate	50 to 60 guns
Fifth Rate	32 to 44 guns
Sixth Rate	20 to 28 guns

Over and above this logical system the Royal Navy, for reasons of deep-set culture, added two other classification terms. Firstly all "rated" ships were also called "post" ships due to the fact they were commanded by confirmed Captains whose promotion to their rank had been "posted" in official documents and secondly, First, Second, Third and, at the start of the period, Fourth Rates were collectively referred to as "Ships of the Line" because they fought in the "Line of Battle".

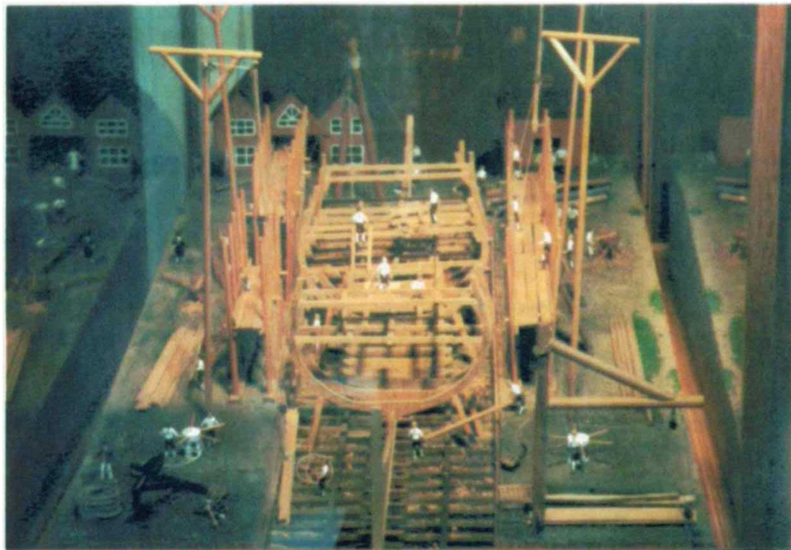
4.2.1. Ships of the Line: The largest warships of the First and Second Rates, had increased in size from the 1750's so as to be able to carry larger and heavier guns, and to be capable of remaining at sea for longer periods of time. By the end of the eighteenth century, wooden construction for hulls was reaching the limit of the number and weight of guns that could be carried[5]. First and Second Rates had three gundecks (Figure 4.1) and to accommodate them were higher in the sides, had more breadth and were more rounded in the bows than warships with two gundecks. The third deck also made them expensive to build and more difficult to man, needing a crew of 750 to 900 men[6] compared to the 550 to 650 men needed to crew a two-decked 74 gun ship[7]. In battle, they presented a large hull area to enemy guns and, because of their large size and large sails, sailing them in adverse winds and heavy weather was more difficult than smaller ships. Guns were arranged by calibre, with the largest and heaviest - 32 pounders on the lowest of the three decks, the main gun deck. Guns were "described" by the weight of the round solid shot fired, thus 32 pounders fired 32 pound shot. As a general rule, the guns on any deck were all of the same calibre to simplify the supply and storage of shot.

First rates were the smallest group of ships in the Royal Navy, and there were only 8 or 10 of them at any time[8]. They needed the largest pieces of timber in their construction and these were the most difficult to obtain. Second Rates, of which there were about twice as many as First Rates, were somewhat smaller, making building, crewing and maintaining them easier. Both rates owed their existence primarily to their role as flagships.

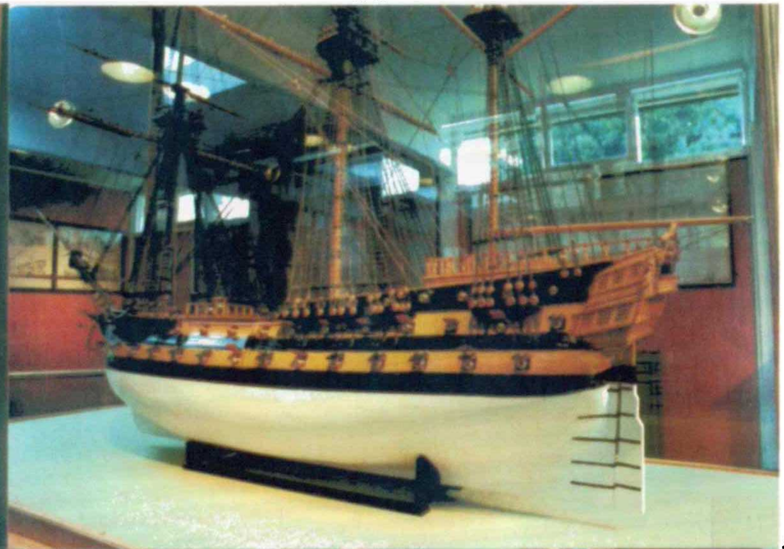
The most numerous group of ships of the line were those carrying 74 guns, (Figure 4.1 [9]) which made up the bulk of the battle fleet, and could be used for many other tasks as well if necessary. In 1793, the Navy had 73 such ships, by 1803 this had risen to 96 and in 1810, the year the fleet was at its largest, there were 160[10]. Third rates could carry a full battery of 32 pounders; considered at that time the most effective gun for naval warfare on the lower of their two gundecks so that they were lighter in construction. In addition, they had a lower centre of gravity and were both faster and easier to handle than First or Second Rates, although they were slower and more cumbersome than frigates. They could make 10 knots in a fair wind and were more comfortable than the smaller ships in heavy weather. As a result, they were considered to have the optimum hull shape and firepower, and it is no surprise that they made up some 85% or more of the battle fleet whose prime purpose was to counter and destroy the battle fleets of Britain's enemies.

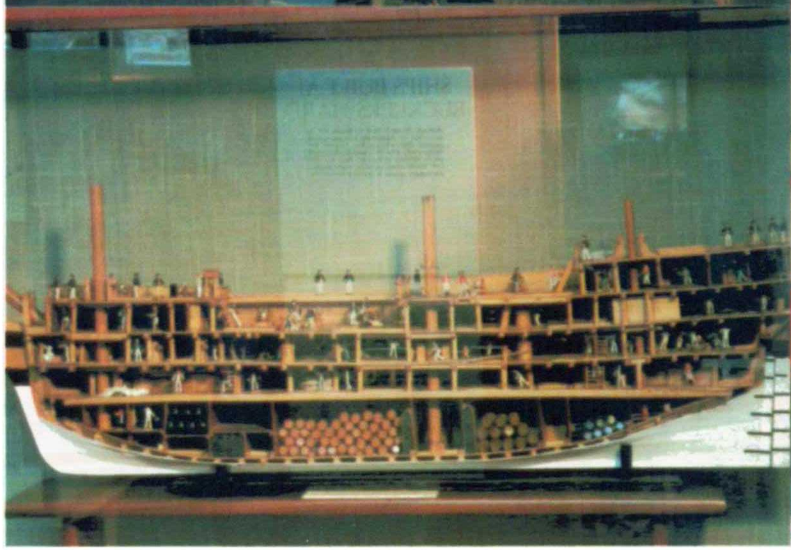
There were in addition Third Rates carrying 64 guns, but these were older ships built before 1785 and still in service in 1790[11]. The largest calibre gun carried by a 64 gun ship was a 24 pounder, so these ships lacked both size and firepower compared to the 74 gun ships.

6TH RATE - BUILDING



3RD RATE





CUTAWAY OF 1ST RATE

FRIGATE

FIGURE 4.1

By the 1790's Fourth Rates, carrying 50 to 60 guns on two gundecks, constituted a small group which was becoming obsolete, although a small number were built during the period 1790 to 1815[12]. They were not considered sufficiently large or robust to lie in the line of battle and those that remained in service had been converted to other purposes, such as troopships. Designed originally to be crewed by 350 to 420[13] men, there was plenty of space to carry troops[14] when the guns were removed and the crew reduced in size.

4.2.2. Frigates: were single-decked warships carrying from 20 to 44 guns, and rated as Fifth and Sixth Rates.(Figure 4.1 [15]) As guns increased in weight and power, the smaller more lightly-built ships were no match for the heavier guns of the bigger ships, so the frigate developed as a type of ship which was designed for speed and independent action. They could undertake any role except that of being in the line of battle, scouting ahead of the battle fleet, escorting high value merchant ships and projecting Britain's maritime power across the oceans of the world. They were able to carry sufficient stores to operate away from major dockyards for at least six months and frequently longer[16]. Their 18 pounder guns were carried on one gundeck and the gunports were higher above the waterline than those of the main gundecks on the ships of the line[17]. Frigates were the Navy's cutting edge and were therefore always in short supply.

4.2.3. Minor War Vessels: Much more numerous than the First to Third Rate Ships of the Line and the Fifth and Sixth Rate Frigates, these were ships of small size and tonnage. Although these vessels could escort convoys, blockade or support combined operations, they were essentially auxiliaries to the fleet, their fighting role was limited, because the 6 pounder guns they carried were no match for those of larger calibre. This group increased most in numbers throughout the period from 99 in 1790 to a peak of 549 in 1809 (Table 3.1 & Figure 3.6).

4.2.3.1. Sloops: were divided into ship-sloops and brig-sloops[18], both carrying up to 20 guns, were very manoeuvrable, and their smaller size and shallower draught meant that they were ideal for work in inshore waters and rivers[19]. As the ship-sloop increased in size and became nearer in type to the "Rated" vessels, a need for an intermediate vessel with a small crew appeared and the brig-sloop filled this opening.

4.2.3.2. Gunboats and Cutters: classed below the sloops, they had one or sometimes two masts. At less than 200 tons and manned by a crew of 50 men, they were armed with a small number of low calibre guns[20]. Their role was that of support - to the fleet carrying dispatches, as coastal defence vessels and in assisting the Customs and Excise against smugglers.

4.2.3.3. Fireships: among the Minor War Vessels are two types which in the twentieth century would be described as specialist weapons systems. The first of these were the fireships, which were built or converted to attack moored or disabled vessels. An enclosed deck was divided to hold explosives and combustible materials, and their gunports were hinged at the bottom so when the fastening burnt through, they fell open, increasing the draught and therefore the rate of combustion. Most fireships spent their lives fitted as sloops and used as general purpose small craft. Smaller fireships were used as 'infernal machines' and these were packed with gunpowder and were intended to explode rather than burn[21].

4.2.3.4. Bomb Vessels: these were the other specialist weapon system; they were heavily built and strengthened to withstand the recoil from the two mortars, one of 13 ins and one of 11 ins[22] which were mounted one behind the other on rotating turntables on the centre line of the ship. The turntables allowed the mortars to be elevated and swivelled like a modern gun turret. They were used for shore bombardment, throwing heavy explosive shells on a high and variable trajectory over a considerable range - about twice as far as 32 pound shot and when employed correctly, they were highly effective

4.2.4. Support Craft: Support craft were of two types, those which were attached to the fleet, and those which belonged to the dockyard. In the first category were warships whose active career was at an end that were converted by the Dockyard for very specific roles. Amongst these roles were those of troopships, stores ships and a few as hospital ships, and all were called upon to support the Army as well as the Navy in campaigns throughout the world. Other vessels, kept within the port area, were used as hulks, which were ships of any rate which had finished their active career at sea; masts and rigging were removed and they were put on a permanent mooring[23]. Some were used as receiving ships, that is as a floating barracks for recruits or men transferring between ships, since there were no shore-based barracks in the nineteenth century and having the men on hulks in the harbour made it more difficult for them to desert. Others were used as prisons, for prisoners of war, as local slop[24] ships, hospitals (or isolation) ships, powder magazines and floating batteries - in short they served vital functions by providing facilities that today would be provided by buildings ashore. However, as well as dockyard effort and time spent on converting them from fighting ships to totally different purposes, they also needed periodic attention to keep them in good repair. These uses for old ships were not confined to vessels from the Royal Navy, since prizes and captures were also used in this way; for example several of the Danish ships taken at Copenhagen in 1807 were not fitted for service in the Royal Navy, but were converted to other roles. The Waldemar, a Third Rate of 80 guns, was fitted as a prison ship in 1812 and the Skiold, a Third Rate of 74 guns, was fitted as a receiving ship in 1811[25].

In the second category were those small craft which moved men and materials about Portsmouth Harbour generally referred to by various names, such as hoys, barges and cutters[26]. Additionally there were boats for moving bulky materials like stone for building or mud dredged out of the harbour entrance - these are generally called lighters, some of which had single masts while others had no motive power of their own. An important vessel with a very specific Dockyard application was the Sheer hulk which was used to hoist masts in and out of ships. To do this, the sheer hulk was fitted with two large spars forming an 'A' frame from which was suspended the requisite blocks and tackles. An interesting example is the Prince William[27] a Third Rate of 64 guns which had been captured from the Spanish in 1780, and later fitted as a sheer hulk by the dockyard in 1791.

4.3. Ship Construction. This brief description of how a warship was built in the eighteenth century is only intended to show the nature and scale of the tasks undertaken by the dockyard. It is fair to say that all the tasks and techniques which were used to build a new warship were also used when they needed to be refitted or repaired[28].

4.3.1. Hull: The major part of any warship is the hull, which consisted in the simplest terms of the keel, frames and planking. It was built on a slipway which had sufficient slope to allow the ship to slide down to the water when the time came to launch her. The construction was mainly of oak and the craftsmen involved at this stage were shipwrights. The timber was cut and roughly shaped with saws on a saw pit, whilst further shaping was done with an adze and completed with a plane. Subsequently, the timbers were fastened together either with wooden pegs called treenails which could be up to 24 inches in length or with metal bolts[29], and hand drills were used to make the holes for bolts. As most of the timbers were very thick, this involved a great deal of work, particularly in the case of a First Rate, where the thickest part through the bottom of the ship over the keel was about 26 inches.

The whole shape of the ship derived from its main frames which were heavily curved and each one was a composite of precisely cut and shaped timbers joined together (Figure 4.1 [30]) to form pieces weighing several tons. Therefore, sheer legs, blocks and tackles, plus considerable human skill and effort were required to move these large pieces into place and rigidly fix them in the correct alignment to each other and the keel. Planking, heated in a steam kiln[31] for one hour for every inch thickness (and one hour for luck), was then sufficiently pliable to be forced into place to create the curved shape of the hull. The hull was completed by external and internal planking which can be seen in Figures 4.2 and 4.3, in which openings for gunports and other points of access were left. Internally, beams and deck timbers were fitted which were supported on specially shaped timbers called knees, since decks had to be strong enough to support the weight of the guns and needed to be cambered to facilitate the drainage of water.

With the hull nearly finished, it was caulked. The word caulking is derived from the French word for hemp, which gave its name to the process and to the caulkers who performed it and its purpose was to make the ship as watertight as possible and to give it rigidity so that the planks did not move and make the vessel difficult to sail. Oakum, which is old rope that has been untwisted and pulled apart, was rolled and forced into the seams between the planks and then covered in melted pitch to prevent it rotting[32].

FIGURE 4.2

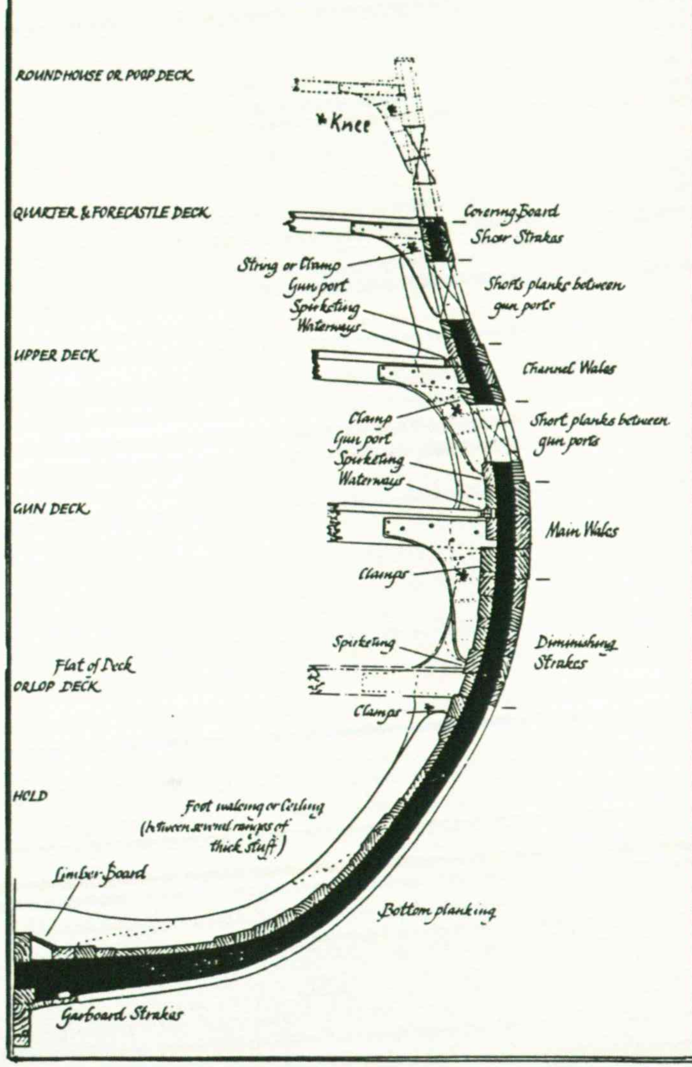
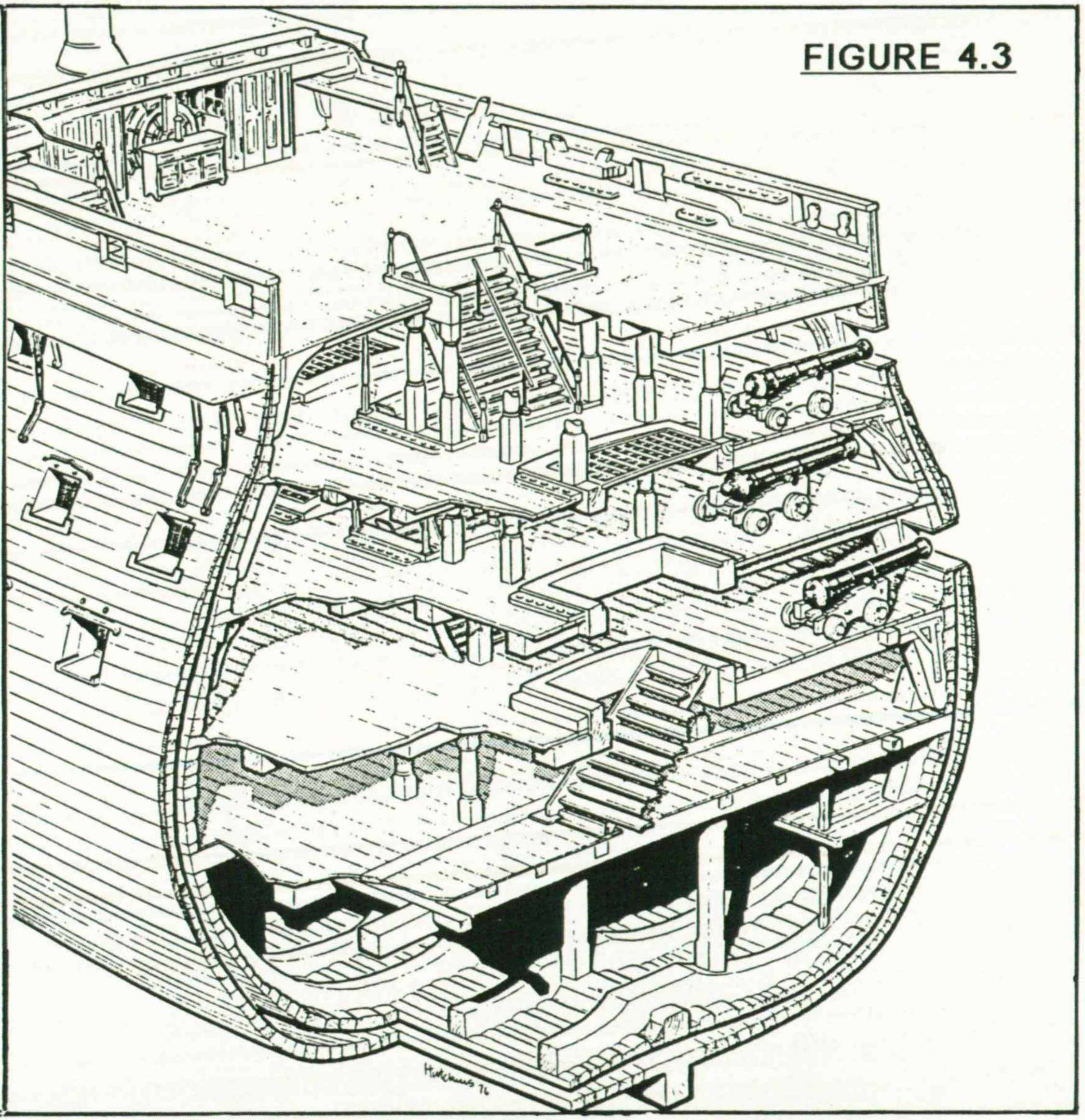


FIGURE 4.3

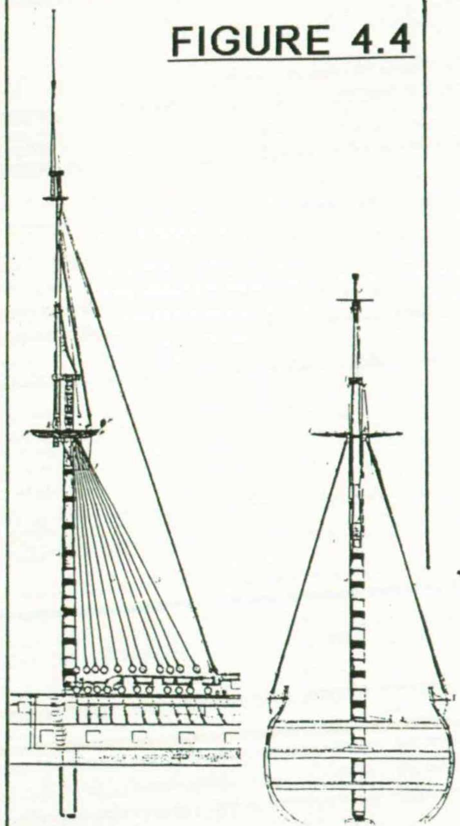


When the hull was completed, the ship was launched and then docked so that her hull could be covered in copper sheets to protect it against rot and the depredations of boring molluscs. If the hull was launched with the copper already in place, there was a risk of it being damaged, a problem which does not arise when floating a ship out of dry dock. The hull was then towed to the sheer hulk for her masts to be fitted and then to a mooring to complete her fitting out. Figure 4.3 is a sectional view through the hull of the First Rate, Victory and it vividly illustrates both the scale and the complexity of the hull of a major warship.

4.3.2. Masts & Yards: All warships of the eighteenth century had three masts and a bowsprit made from fir[33], which was a flexible wood which would 'give' with the wind. In order to make them to the required height, masts were made in three Sections (see Figure 4.4) called the lower mast, topmast and topgallant mast. The lower mast was a "made" mast consisting of several pieces of fir fitted together to the required length and size, and slightly tapered from bottom to top. To ensure the pieces stayed tightly together they were bound at three foot intervals with rope, or mast hoops were fitted, where a ring of iron slightly smaller than the diameter of the mast was heated and driven onto the mast as tightly as possible. The diameter of the lower mast of a ship-of-the-line was about three foot, and it passed right through the ship and rested on a mast step on the keel. The centre Section of the mast, was also a "made" mast, ie it needed several lengths of timber to get it to the correct length and diameter. The top mast however was made from a single tree trunk, called a "stick".

The yards, shown in Figure 4.5, crossed the masts and bowsprit, in the horizontal, at right angles and were also made from fir with the lowest and longest on each mast being wider than the breadth of the hull. Like the masts, they were composed of several lengths of wood joined together and shaped so they tapered slightly at each end.

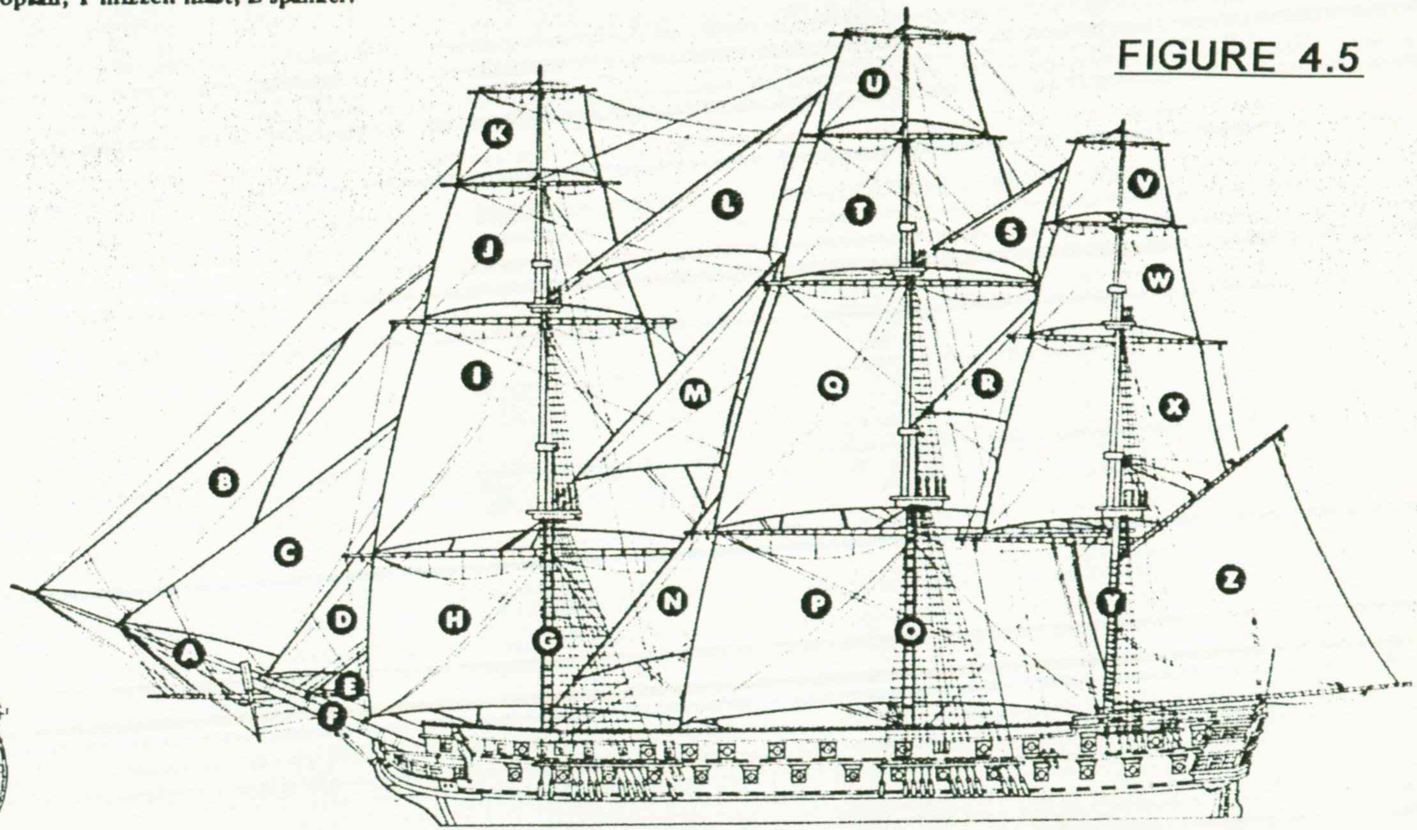
FIGURE 4.4



The sail arrangement of a large early nineteenth century frigate:

A jib boom; B flying jib; C outer jib; D inner jib; E fore staysail; F bowsprit; G foremast; H fore course; I fore topsail; J fore topgallant; K fore royal; L main royal staysail; M main topgallant staysail; N main topmast staysail; O main mast; P main course; Q main topsail; R mizzen topgallant staysail; S mizzen royal staysail; T main topgallant; U main royal; V mizzen royal; W mizzen topgallant; X mizzen topsail; Y mizzen mast; Z spanker.

FIGURE 4.5



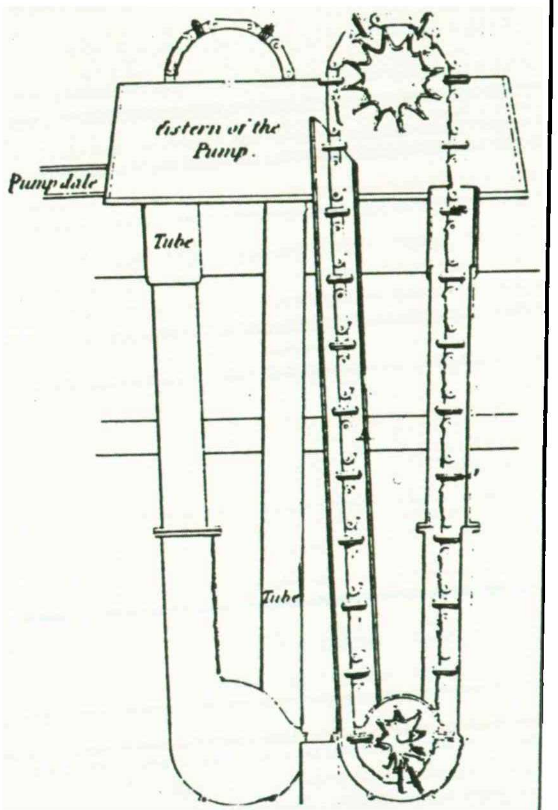
4.3.3. Rigging & Sails: The fitting out involved the setting up of the rigging which was done by gangs of contract riggers. The rigging was made from hemp rope, much of which was prepared in workshops in the dockyard before being taken out to the ship. In fact there were two types of rigging, standing and running; the function of the former was to support the masts and bowsprit in position (see Figure 4.4), and it could not be moved. The latter controlled the yards and hoisted and lowered the sails (see Figure 4.5), which involved the use of many blocks which could redirect lines as well as getting extra purchase on them, so that the sails could be moved as easily as possible.

A ship-of-the-line with three masts and their respective yards carried a set of thirty two sails. Sails were either square (quadrilateral) or fore and aft (triangular) (Figure 4.5), square sails were spread on the yards, and fore and aft sails were attached to the standing rigging and were carried between the masts and as jibs. Although the Navy purchased its canvas ready woven from flax or hemp, sails were cut and made by hand in the dockyard's sail loft. Different weights of canvas were used for different sails and weather conditions; the heaviest was No.1 canvas which was used for storm sails, and the lightest No.10 was used for clothing, screens and other items which would make living conditions more comfortable.

The whole design of masts, yards and rigging was a complicated but largely empirical process of distributing forces, depending heavily on the expertise and co-operation between the Master Sailmaker and Master Rigger. The masts and yards supported the vertical forces arising from their own weight and the dynamic component of the sail forces. Whilst the sails and rigging took the full horizontal forces which propelled the ship, in effect they were the ship's engine.

4.3.4. Internal Fittings: The cutaway model shown in Figure 4.1 gives an idea of how the internal layout of a warship could have looked. Included were cabins for the officers, - the crew lived on the gun decks - storerooms and working space for the ship's specialists such as bosun, carpenters and sailmakers and surgeon, together with lockable storage for spirits and other precious stores, while Ordnance stores like shot and powder had their own special stowage spaces. Ballast of iron bars and shingle was put into the bottom of the hull and on top of this went the casks of water and provisions. There was in addition, space to stow the anchor cables.

FIGURE 4.6

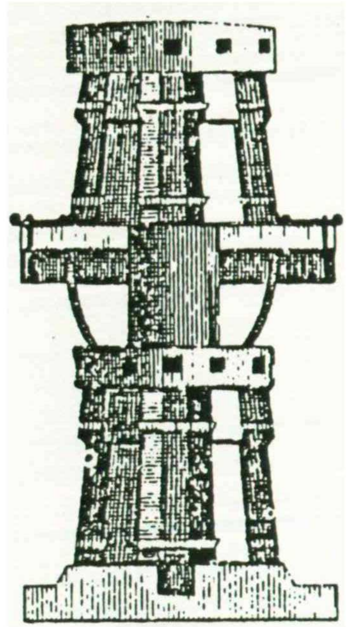


CHAIN PUMP

SHIP'S

FITTINGS

DOUBLE CAPSTAN



The ships fittings included her steering gear, four anchors, the pumps to remove water from the bilges under the hold, the capstans (Figure 4.6 shows these two ship's "machines"), a stove for cooking and the ship's boats. Finally the ship would have been painted and decorated.

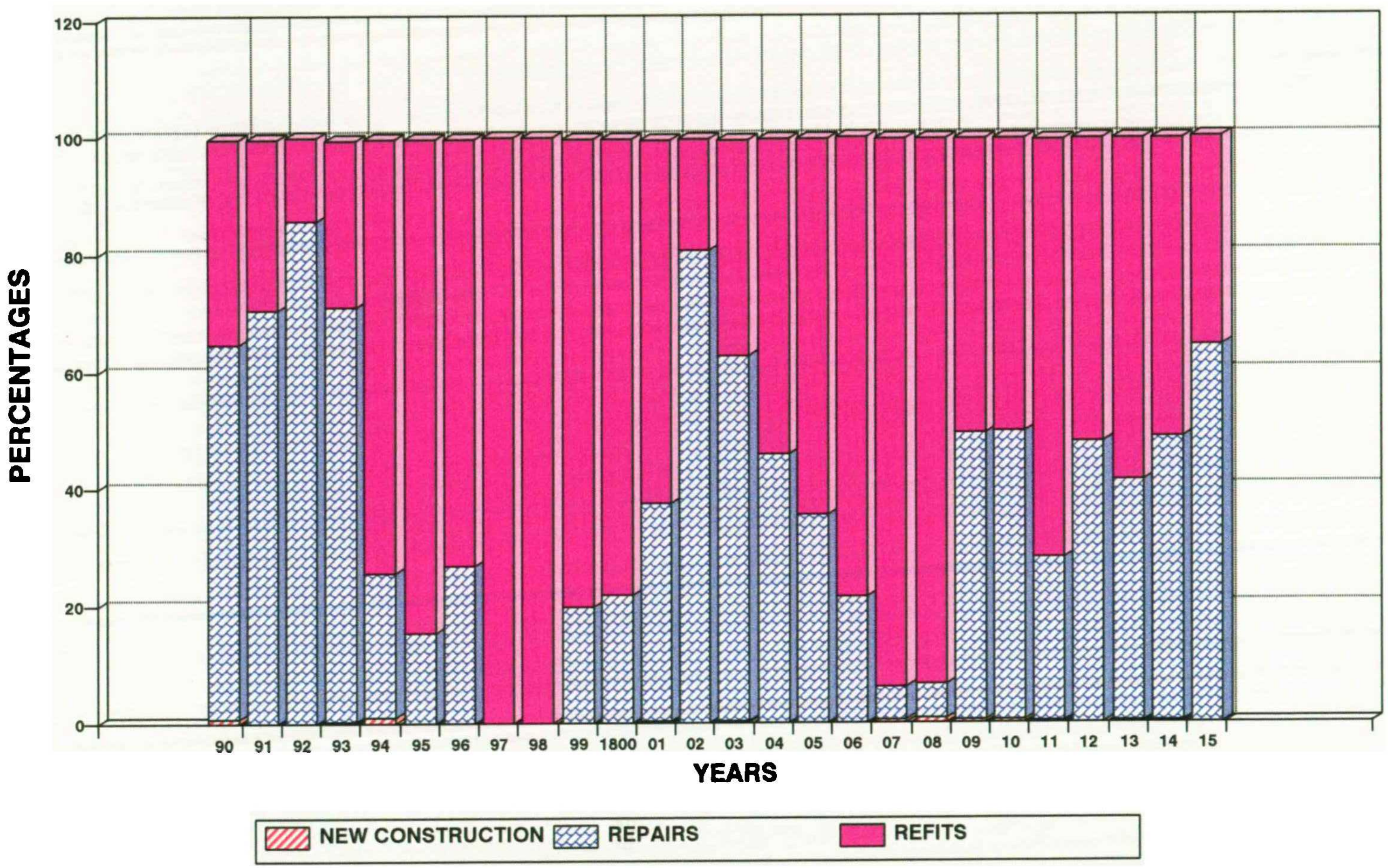
4.4. Dockyard Tasks. The focus of Dockyard work in peace was, and is, significantly different from that in war. In the former, its efforts were aimed at maintaining "the Fleet in being", bearing in mind that in the late eighteenth century more than half the ships were in reserve. However in war, the Dockyard's efforts were totally focused on sustaining the Fleet's ability to carry out its day to day tasks.

At the start of the American War of Independence in 1774, the fleet was in sufficient disarray to cause the Royal Navy and the Government considerable embarrassment. When the war ended in 1783, senior naval officers like Sir Charles Middleton, who was then Controller of the Navy, were determined to initiate a programme of maintenance and repair for the fleet so that the ships were better prepared in the future. This concept was supported and funded on the Government's side by William Pitt[34] and it is to it's credit that the Napoleonic Wars found the British Line of Battle fleet available in relatively short order.

Over the centuries, the clerks of the Admiralty and Navy Boards devised a number of terms to differentiate between the various Dockyard activities and means of funding them. In the period 1790 - 1815, two of the principal categorisations were Repairs and Refits the nature of which is discussed in some detail on pages 71 and 74 respectively. Repairs involved a range of activities from the small scale to major rebuilds or conversions. It was the major repairs plus refit work of a preventive nature which was abandoned in war in favour of the operational imperatives of getting ships out to sea as quickly as possible, without regard to considerations of the ship's long-term future. To the terms Repairs and Refitting should be added a third expression - Fitting. This term is used to describe both the work needed for the Dockyard to complete a new construction and a repaired or re-built hull, to the level at which they could be sent to sea. The next few sub-paragraphs explain the basic differences between New Construction, Repairs and Refitting and Figure 4.7 shows the percentages of Dockyard work, measured in terms of Dock Days, devoted each year to the three different tasks whilst Figure 4.7.1 shows the spread of the actual days. The annual variations in effort assigned to each of these task areas are important because they reflect how the Dockyard Management adjusted their work load to meet the priorities of keeping the operational Fleet at sea.

FIGURE 4.7

RATIOs (%), N.CONSTR., REPAIRS, REFITS
IN TERMS OF DOCK DAYS/YEAR



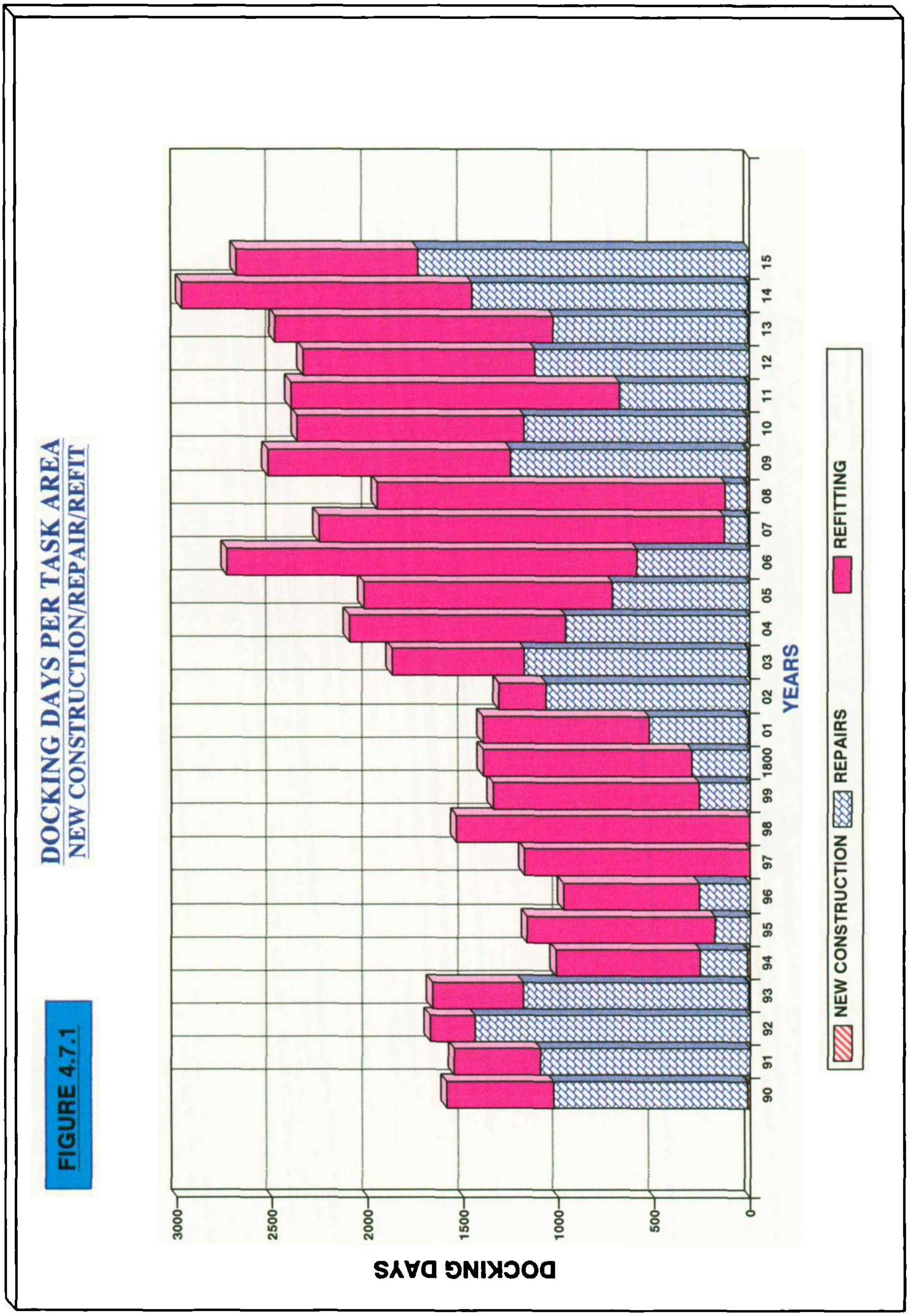


FIGURE 4.7.1
DOCKING DAYS PER TASK AREA
NEW CONSTRUCTION/REPAIR/REFIT
DOCKING DAYS
0
500
1000
1500
2000
2500
3000
YEARS
90
91
92
93
94
95
96
97
98
99
1800
01
02
03
04
05
06
07
08
09
10
11
12
13
14
15
NEW CONSTRUCTION
REPAIRS
REFITTING

In peacetime particularly it was more than likely that ships being built or undergoing major repairs were not worked on for all their time on the slipway or indeed when in dock. Certainly it can be suggested that both building and repair work was used by the Master Shipwright as a source of ready effort to resource emergency or more urgent tasks. This all too often applied in peacetime when financial resources were inadequate to match the total work in hand. In part this was due to the fact that the Admiralty used its money in peacetime to pay off debts incurred during past periods of war.

4.4.1. New Construction: As a matter of policy the Admiralty Board preferred to build their ships in the Royal Dockyards as they felt that the standards of materials and workmanship were superior to those of ships built on contract in merchant yards, and they also found it easier to monitor the construction process in the Royal Yards. However in the period 1793 to 1815 only 41 of the 78 Line of Battle Ships and 60 of the 627 Frigates and below built for the Royal Navy were constructed in the Royal Dockyards[35]. Figure 4.8 (and Tables 4.1) show that shipbuilding effectively stopped in Portsmouth when war started and indeed only four ships, started before the war, were completed prior to 1806. Thereafter, there was a modest output in every year up to 1814 except 1812. Certainly Figure 4.8 shows that with 5 building slips available, there was ample capacity to build the Caissons and Dredger discussed in Chapter 7.

Portsmouth also docked, coppered and fitted out the ships built in local merchant yards of which there were some 14 within 20 miles of Portsmouth (Figure 4.9) and one of these, Bucklers Hard, built one Third Rate, three Fifth Rates, two sloops and a stores ship between 1793 and 1801.

4.4.2. Repairs: The clerks of the Admiralty and Navy Board designated repairs as small, middling or medium, middling-large and large or great, depending on the amount of work to be undertaken and thus the length of time a ship would occupy a dock. Large repairs were frequently in the nature of a re-build and were accordingly nearly as expensive as building a new ship. Indeed it was suggested on several occasions that it was more desirable to start a new ship than rebuild an old one[36] as it was not always possible to be completely accurate in estimating the extent of repairs needed until an old ship was docked, opened and the inner timbers surveyed.

TABLE 4.1 - PORTSMOUTH NEW BUILDS - NUMBERS COMPLETING BUILD IN ANY ONE YEAR

SHIP TYPES		90	91	92	93	94	95	96	97	98	99	1800	01	02
A	1ST RATE													
	2ND RATE					1							1	
B	3 & 4th													1
C	5th Rates													
E	6th Rates													
F	Minor V.	1			1									

TABLE 4.1A	TOTAL	90	91	92	93	94	95	96	97	98	99	1800	01	02
		1			1	1							1	1

SHIP TYPES		TOTAL BUILT	03	04	05	06	07	08	09	10	11	12	13	14	15	16
A	1ST RATE	1								1						
	2ND RATE	2														
B	3 & 4th	2					1									
C	5th Rates	2				1				1						
E	6th Rates	2						1			1					
F	Minor V.	7						1	1	1			1	1		
	TOTAL	16														

TABLE 4.1A	TOTAL	03	04	05	06	07	08	09	10	11	12	13	14	15	16
					1	1	2	1	3	1		1	1		

71a

FIGURE 4.8

SHIPS LAUNCHED IN PORTSMOUTH - PER YEAR BY CLASSES

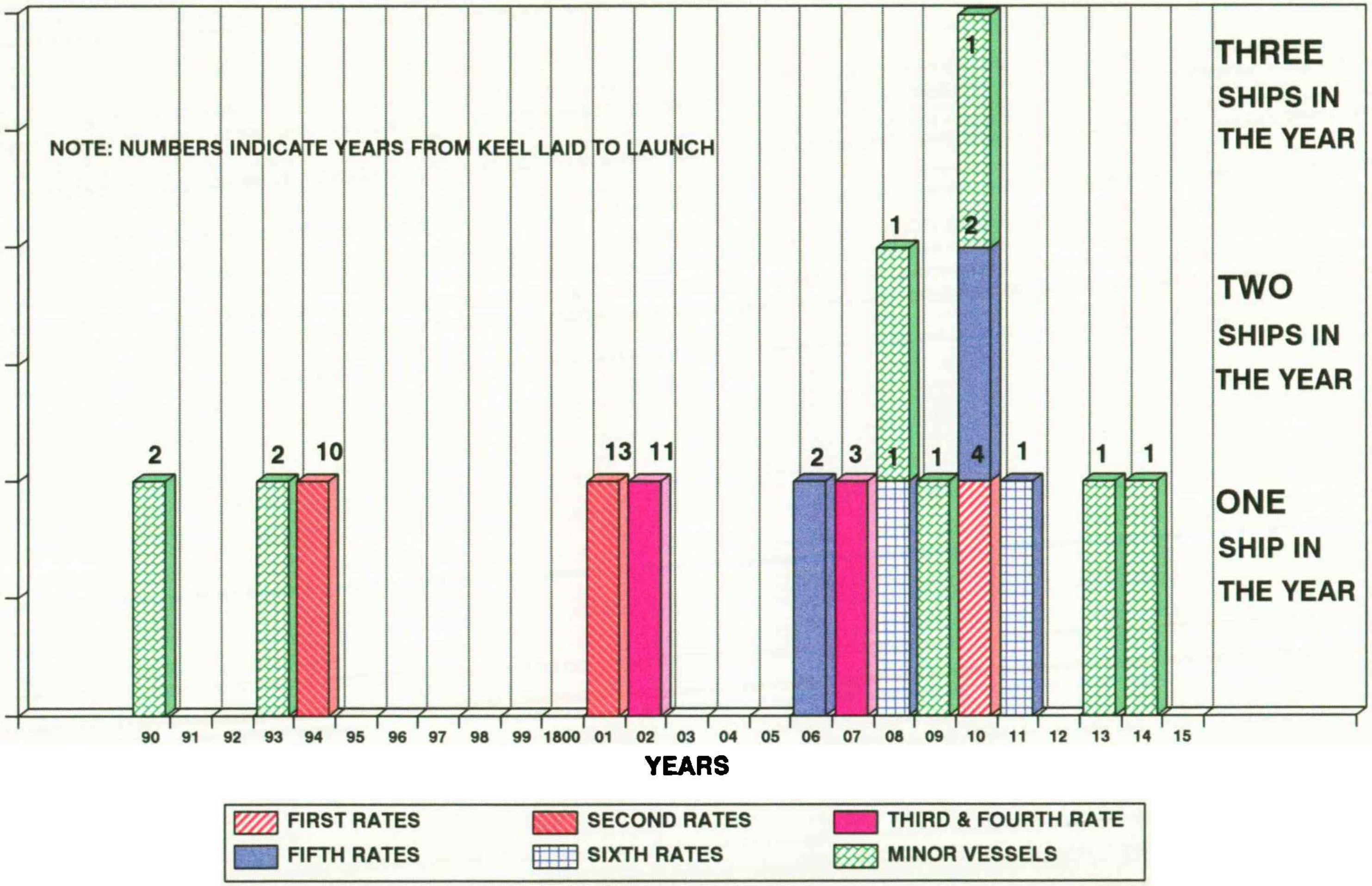
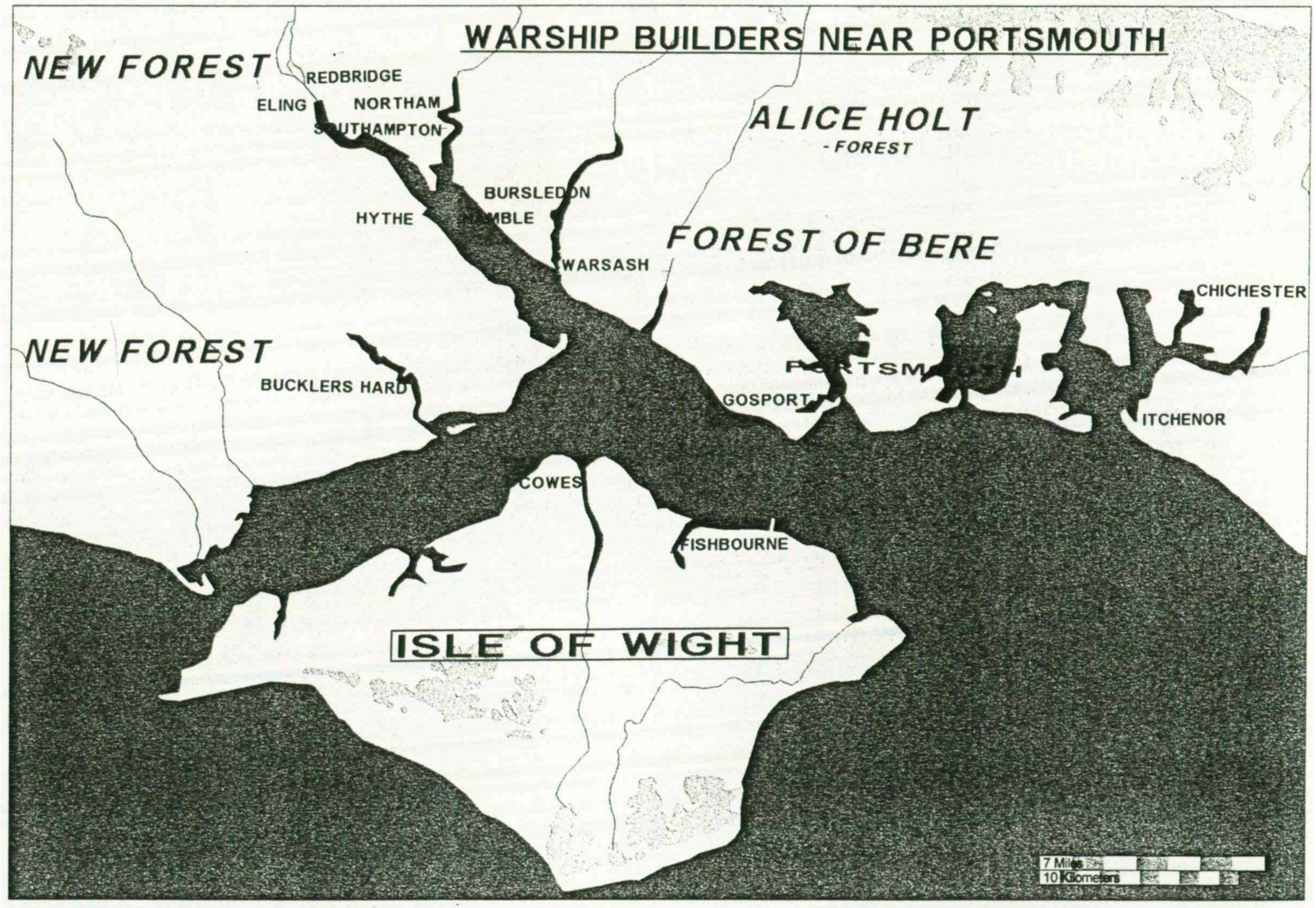


FIGURE 4.9


WARSHIP BUILDERS NEAR PORTSMOUTH
NEW FOREST
REDBRIDGE
ELING
NORTHAM
SOUTHAMPTON
ALICE HOLT
- FOREST
BURSLEDON
HYTHE
FOREST OF BERE
WARSASH
CHICHESTER
NEW FOREST
BUCKLERS HARD
GOSPORT
ITCHENOR
COWES
FISHBOURNE
ISLE OF WIGHT
7 Miles
10 Kilometers

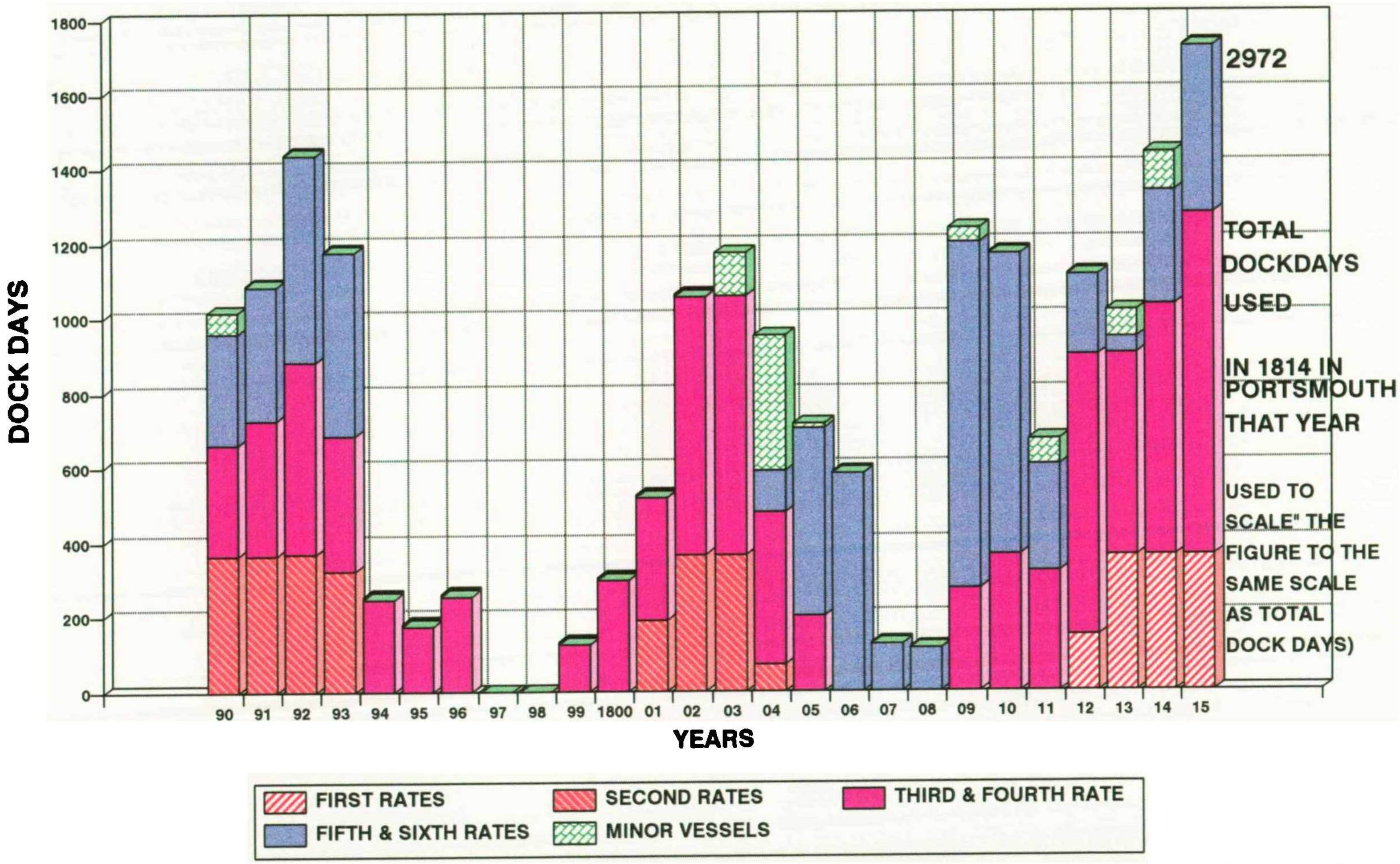
A better reason for doing extensive repairs on old ships was often the shortage of the large and specific shapes of timber needed for ship building. Obviously an old ship already had all the necessary timbers even if some had to be repaired or replaced, while for a new ship a great deal of properly seasoned timber of the right sizes and shapes had to be found.

As with new builds, Portsmouth did not do any extensive repairs to Royal Navy ships from completing Triumph in October 1794 until Elephant was docked in August 1799, although Impetueuse, a captured French ship was repaired from July 1795 to September 1796. During the Peace of Amiens the Repair load again rose but reduced steadily thereafter until 1808. However from 1809 it increased sharply as the effects of the long war could no longer be ignored and by 1814 it was back to pre-war levels (Figure 4.10) with ships docked for large-scale work as the war drew to a close.

4.4.3. Refitting: This process formed the main task of Portsmouth dockyard during the war and for which New Construction and Repair work was sacrificed. This was not surprising since Portsmouth undertook by far greatest number of refits compared to the other Yards. In the period 15 May - 26 December 1805, for ships bigger than gunboats, Deptford and Chatham did no refits whilst Woolwich undertook 4, Sheerness 37, Plymouth 24 and Portsmouth 48[37]. Essentially Refits involved the regular maintenance of the ships, without which they would have become non-operational. The work included docking to clean the hull of weed and debris and any necessary work on the sheathing. This had been done roughly every three years during the eighteenth century and was known as a "triennial trimming". However the introduction of copper sheathing for hulls during the American War of Independence (1774-1783) increased the interval needed between dockings as the hull remained free of weed for somewhat longer - four years or so all other factors being equal.

FIGURE 4.10

REPAIRS - DOCK DAYS PER YEAR
BY CLASSES



4.5. The Purpose and Basis of The Dockyard Output Analysis. In terms of identifying the opportunities for, and the value of, introducing new technology into Portsmouth Dockyard, it was considered necessary to attempt a degree of quantification of the Dockyard's work load. This quantification can best be described as an output analysis in terms of the identifiable work output from the Dockyard which was firstly limited by the availability of data some two hundred years on and secondly was firmly constrained to the aim of giving both substance and authority to subsequent assessments of the value/effectiveness of the available new technology which was/was not applied in Portsmouth Dockyard. In pursuit of this aim the analysis was confined in scope to two areas of the "Yard's" activities which, collectively, could reasonably be taken to be representative (from the standpoint of this thesis) of the yard's activities as a whole. The same principle was also firmly applied to the resource, or input, analysis which is discussed in the next chapter. Additionally the processing of the collected data was restricted to that required to illuminate the pattern of change, or changes, across the period. Hence the detailed analysis of particular year on year changes which departed from the general pattern was only pursued if that departure was assessed as being germane to the examination of the effect of new technology on the yard.

In these circumstances it would be surprising if all readers, from widely different backgrounds and experiences, were to agree in toto on what should/should not have been explored in either greater or lesser detail. The author merely claims to have tried to include what is relevant and avoid irrelevant points however interesting. Undoubtedly a number of seemingly fruitful areas for further detailed studies of the management and work of Portsmouth Dockyard around, and immediately after, the Napoleonic wars are clearly identifiable from the work presented in this thesis.

Later Chapters draw significantly on the analysis in this and the following chapter and it is true to say that without these analyses it would have been impossible to pursue reasoned discussion, and certainly to offer "value judgements" on many of the technological advances which were available to Portsmouth Dockyard in the period but which apparently were not exploited. More importantly it would not have been possible to demonstrate a positive value for many of those advances which were exploited. That said it must never be forgotten that the output of these analyses is based on selected and representative data - **not complete data** - thus the reader is presented with evidence in support of an assessment rather than evidence which proves an assessment.

The veracity of this analysis depends from the outset on a comprehensive listing of the ships which were docked in Portsmouth, what was done to them and when. The details of 532 gunboats, cutters and other small craft were not included as their records were too sketchy to be certain if they were docked or not[38]. The source of the material used is the Admiralty Progress Books, which were a compilation of returns by the Royal Dockyards to the Admiralty Board of work in progress. The data covers the dates of arriving in harbour, docking, undocking and sailing, type of work done during docking and the nature of repair, plus costs. Most of the information for the years 1790 to 1802 is contained in the Progress Books ADM/180/4 to 9 and those for 1803 to 1815 in ADM/180/10 to 13.

Inevitably not all the individual records are complete and there are a number of apparent inconsistencies. However the basic details of ships entering the Dockyard, the dry docks and when they sailed to rejoin the fleet are well over 75% complete and this is more than adequate to support this study especially as the "gaps" in the data relating to dry docking could safely be completed by using class averages for the year(s) concerned. Unfortunately the data for costs across the period was less than 50% complete and was presented in such a way that it was not possible to separate readily the dockyard materials, manpower and stores elements. Fortunately shortcomings in this area, whilst regrettable, are not a serious constraint as detailed analysis of the economics of the Dockyard's work are not germane to this thesis.

The data relating to "dockings" is particularly significant in that it is generally true to say that the dry docks were the "choke point" in the operation of the Dockyard and consequently ships did not often lie unavoidably idle in dry dock. The word "unavoidable" is deliberate in as much as there was inevitably a significant amount of "waiting time" when a ship entered or left the dry docks as those facilities were emptied or flooded and whilst ships waited for the tide to reach a level at which they could move in/out. The reduction of this was very much part of the driving force behind the development of the Portsmouth Dry Docks in the late 1790s and these re-structured facilities were supplemented with technological advances to the extent that this "waiting time" was subsequently appreciably reduced.

All the evidence suggests that it was only a few big ships (mostly in peace time) which were kept in dry dock for longer than necessary and where this did happen it is not difficult to identify. For the remainder of the time the docking data provides a remarkably illuminating measure of dockyard work and has a surprising correlation with the size of the fleet, the number of sailings from the dockyard and, as will be seen later, the size of the dockyard work force. On the other hand data relating to the periods spent in the dockyard before and after docking is much less reliable. There was often considerable "slack time" between ships entering the dockyard and moving into the dry docks and, from the figures, it is hard to avoid the belief that quite often ships spent considerable time lying idle. Once out of dry dock ships again appeared to face periods of idleness especially if they were being kept in reserve or used as "hulks" for accommodation, prison or hospital purposes. For these reasons data relating to these two periods has not been examined in any detail.

As long as there has been a Royal Navy - certainly since the time of Henry VIII, and up to the 1990s - the standard of workmanship of the Royal Dockyards has always been the subject of adverse criticism. Even as late as 1993 when the Dockyards were transferred to commercial management the Officers and ratings of the fleet lost no opportunity to point out the Royal Yard's inadequate workmanship. The period of the Napoleonic wars was no exception. Undoubtedly there were management inadequacies and restrictive working practices and it is no doubt also true that there were serious shortcomings in the standards of some of the material the Dockyards bought in from contractors. Some of these shortcomings could be attributed to genuine shortages and inadequate sources of alternative supplies; some involved outright "war profiting". However, as the recent commercialisation of the dockyards has shown, a major factor has always been the lack of definition of the work to be done before a ship was "taken in hand". Here Ships' Officers have invariably been guilty in that they have traditionally attempted to include in refits their private "top priorities" regardless of anything the Dockyard might have said about the lack of available resources. The major problem has therefore always been that it is not until a ship is docked down and she is opened up to inspection that the true amount of unavoidable work could be determined. As a result - given the dictates of refit time and resource budgets - history has shown that there has always been a gap between expectations from and achievements out of, a refit. On occasions, as the Dockyard sought to "balance the Books", a degree of lower standards of workmanship than the Fleet expected was inevitable.

It has therefore been important to construct any assessment or analysis of the dockyard work load around "quantity" and avoid the whole question of "quality". Quantity is measurable to a reasonable degree whilst quality is most certainly not. Even less can shortcomings in quality be confidently attributed to particular causes. All these factors were borne in mind when developing the database which was used for this analysis. For the period 1790 to 1815 some one thousand eight hundred and ten individual records each containing the following original data were collected:

1 - Name	2. - Rate	3.- Guns	4.- Arrived Dockyard
5. - Docked	6. - Undocked	7.- Sailed	8. - Tonnage
9. - Built at	10.- Date Completed	11. Classification of Dockyard Wk.	12.- Work done in dock
13 - Cost of hull mast & yards.	14.- Cost of rigging & stores	15. Remarks	

Over and above these 15 "original" fields there are 16 "calculated" fields which are derived from the original data and generate the figures used in the numerical analysis. Some of these are presented in Figures 4.11 to 4.17.1 and their associated tables (Tables 4.2 - 4.9) from which the graphs are generated.

4.6. Detail of The "Output" Analysis. This paragraph explains the key figure types which were used in the analysis. These were:

4.6.1. Dockings: The number of ships per year which were in or passed through the dry dock complex - by rate and in total for each year. Ships entering the dockyard were actually dry docked on some 80%+ of their periods in the Yard and the occasions when they were not were invariably associated with minimal demands for dockyard effort. It is reasonable therefore to use the number of Dockings per year as an initial indicator of increases and decreases in the overall dockyard's workload. It cannot be used as anything other than as an initial indicator since it neither reflects any measure of the time involved with a particular docking nor does it involve any indication of the scale of work involved on any day of the docking.

4.6.2. Dock Days: The number of days (calculated by subtracting the undocking date from the docking date) a ship spent in a year in the dry dock complex - by rate and in total for each year. Using days in dock rather than dockings themselves overcomes the problem of accounting for time in dock whilst still not addressing the problem of taking account of the scale of daily work on a particular ship. As has already been stated, it is known that time in Dry Dock was at a premium during times of high Dockyard work loading and hence it seemed reasonable to assume that "slack time" (as distinct from unavoidable waiting time) in the dry docks was kept to a minimum - certainly in war time. During Refits, and indeed during Repairs, a significant amount of the work which had to be done on the ship was done whilst it was in dry dock. The more work that had to be done; the longer the ship was in dry dock. Time in dry dock has therefore been taken as the first part of the "Representative" figure of the work on a ship's hull.

Additionally, it should be noted that the average length of time it took to copper a new ship, which did not involve taking off the old copper, was slightly less than 5 days and as such the resultant Dockyard work load was relatively insignificant. Thus, the dock days involved with coppering new ships built outside Portsmouth has not, in the analysis, been separately identified from those involved with coppering any other ship which enters the yard from sea.

4.6.3. Ton Dock Days: A figure combining the days a ship spent in a year in dock with its tonnage - by rate and in total for each year. The tonnage was an Admiralty calculated figure which gave a measure of burden, that is the volume of the hull, not of displacement which is a measure of weight. This formula could be applied to all ships, including those which had been captured and was calculated by multiplying the length of keel for tonnage x breadth x depth in hold and dividing by 94[39]. For example, the Mars, a Third Rate had a keel length for tonnage of 144 feet 3 ins , breadth of 49 feet and depth in hold of 20 feet. Her tonnage was:

$$\frac{144'\ 3" \times 49' \times 20'}{94} \qquad = 1842\ \&\ 24/94\text{ths tons}$$ [40]

Figures were rounded up or down for the purposes of calculation. Use of this "derived" figure allowed all ships to be measured on a common scale. This in turn permits the use of the figure in a representation of the daily work load in the Dockyard. This is done by multiplying the tonnage by the time in Dock and the resultant figure gives the first full "Representative" figure for dockyard work and is called "Ton Dock Days"

4.6.4. Sailings: The number of ships sailing per year from Portsmouth Dockyard - by rate and in total per year. It can be argued that the number of ships sailing from the Dockyard is the one true output measurement in that it is the only one the Operational Commanders were interested in. Their attitude was summed up by the following - Never mind the dockyard's problems - get us the ships we need to fight the war.

There is invariably a difference between Sailing and Docking figures and this is as it should be because whilst all ships including harbour service vessels such as prison ships, hospital ships, accommodation vessels, dockyard hulks, and of course ships in Ordinary/Reserve routinely went through the dry docks, only those ships deploying to the fleet are actually counted under the sailing numbers. The significance of this is whilst Dockings provide a sound basis for assessing hull and timber work, Sailings provide a much more appropriate basis for assessing work on sails and rigging since, particularly the former, were little involved in the refit of harbour service and ships in Ordinary.

4.6.5. Ton Sailings: The problem of Sailings not taking account of the size of individual ships (and hence their sail and rigging demands) has been overcome by again employing the ship's tonnage and equating it with sailings to give "Ton Sailings". This gives the second "Representative" measurement of Dockyard work output. Like Dock Days, and Ton Dock Days it is rightly dominated by the bigger ships.

There is no equivalent figure to Ton Dock Days since it is quite impossible to get a feel, let alone quantify, the time devoted to work on sails and rigging particularly as so much of the manufacture of rope and all the manufacture of canvas was done on contract or in other Royal Dockyards.

4.6.6. Average Time In Dock: There has always been considerable support for the hypothesis that the Controller of the Navy (and hence Dockyard Management), faced with severe resource limitations, met his top operational priorities by progressively reducing the work done on ships to a level matched to only essential work necessary to get ships back to sea without regard to longer term needs to sustain the expected life of the hulls concerned. By the start of the 1800s this management practice steadily became impractical and a return to a degree of "duality" (both short and long term work) was unavoidable. Calculation of "Average Time in Dock" was looked at as a means illustrating the degree of these changes.

The remainder of this chapter concentrates on what can be learnt from this analysis. In general the "trends" across successive years are of more significance than the absolute figures in any one year particularly because there is no way of preventing the presence of just one First or Second Rate in dock for an extended period dominating the total dock days figures for that year. Many might well suggest that this domination of the dockyard's work by a very small number of the Navy's major capital ships is unrealistic. In fact the reverse is true and the situation continues to this day whereby the presence of an Aircraft Carrier in a Dockyard for major refit dominates the utilisation of Dockyard effort for that year.

4.7. Outcome of Output Analysis. The principle output of the analysis are the figures (graphs) and tables. These will become more significant when they are used in conjunction with the figures and tables in Chapter 5 (input analysis - Dockyard personnel). Figures 4.11 to 4.17.1 and their associated Tables show the outcome of the Analysis of Portsmouth Dockyard's output. It is helpful to look at the Chapter 4 Figures and Tables against Figures 3.6 - 3.6.4, supported by Tables 3.1 and 3.1.1, in Chapter 3. Those figures and tables show the composition of the Fleet as a whole and the percentages and numbers of each major ship group that were in Fleet (operational) service, were used for Harbour Duties or were in Ordinary (Reserve).

4.7.1. Dockings (Number of): These figures are best read in conjunction with those for Dock Days. However, on their own Figure 4.11 and Table 4.2 show the pattern and numbers of dockings per class of ship per year across the period. 1792 - 94 was a period of getting ships out from "Ordinary" to the Fleet but the relative "flatness" of pattern from 1794 - 1800 gives some support to the statement that the Dry Docks were very much a "choke" point in the Dockyard process and the Yard was "resource limited" in the availability of dry docks until improvements were made in that area. Reference back to Figures 4.7 and 4.7.1 show that in this period the use of the dry docks was over 80% devoted to Refit work. The growth in the number of dockings after 1804 owes most to the minor vessels and that accords with the increase of those ships in the fleet as a whole.

TABLE 4.2 - DOCKINGS PER YEAR - BY CLASS

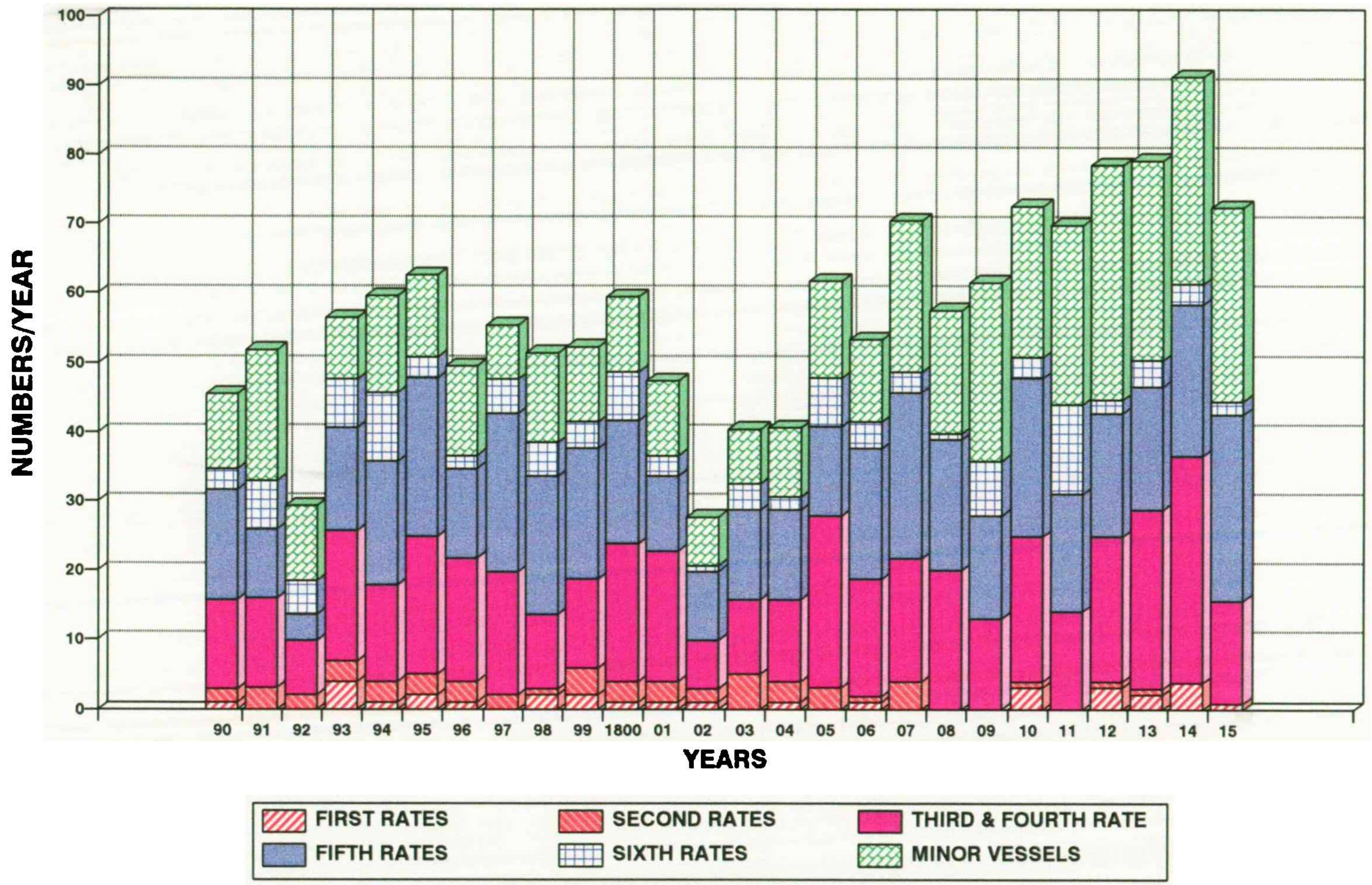
DOCKINGS/YEAR		1790	1791	1792	1793	1794	1795	1796	1797	1798	1799	1800	1801	1802
A	1ST Rates	1	0	0	4	1	2	1	0	2	2	1	1	1
B	2nd Rates	2	3	2	3	3	3	3	2	1	4	3	3	2
C	3 & 4th	13	13	8	19	14	20	18	18	11	13	20	19	7
E	5th Rates	16	10	4	15	18	23	13	23	20	19	18	11	10
F	6th Rates	3	7	5	7	10	3	2	5	5	4	7	3	1
G	Minor V.	11	19	11	9	14	12	13	8	13	11	11	11	7
TABLE 4.2A	TOTAL	46	52	30	57	60	63	50	56	52	53	60	48	28

DOCKINGS/YEAR		1803	1804	1805	1806	1807	1808	1809	1810	1811	1812	1813	1814	1815	1816
A	1ST Rates	0	1	0	1	0	0	0	3	0	3	2	4	1	1
B	2nd Rates	5	3	3	1	4	0	0	1	0	1	1	0	0	0
C	3 & 4th	11	12	25	17	18	20	13	21	14	21	26	33	15	3
E	5th Rates	13	13	13	19	24	19	15	23	17	18	18	22	27	1
F	6th Rates	4	2	7	4	3	1	8	3	13	2	4	3	2	0
G	Minor V.	8	10	14	12	22	18	26	22	26	34	29	30	28	0
TABLE 4.2B	TOTAL	41	41	62	54	71	58	62	73	70	79	80	92	73	5

82a

FIGURE 4.11

DOCKINGS PER YEAR
BY CLASSES



4.7.2. Dock Days: Figure 4.12 and Table 4.3 show the pattern of dock days per class of ship per year across the period. The relatively low number of Dock Days in the period 1794 - 1800 has to be read in conjunction with the growth in the actual number of dockings and this gives weight to the assertion that the Dockyard was only doing the bare minimum of work necessary to get ships out to sea. Indeed the peak in dockings prior to 1803 occurred in 1794 which was when the number of dock days was less than in any other year except 1796. Interestingly, reference to Figure 3.6.2 shows that Line of battle ships reached their highest operational availability level (63%+) between 1795 and 1798 whilst it is significant that the number of dock days did not actually peak until 1814 - some four years after the Fleet numbers peaked in 1809 (Figure 3.6).

4.7.3. Ton Dock Days: Figure 4.13 and Table 4.4 show the pattern of ton dock days per class of ship per year across the period. The dominance by the First, Second and Third Rates of the Dockyard work load is clearly revealed. The growth in the load involved with frigates is greater than that which could be expected from the increase in their actual numbers thus adding weight to the view that as the ships grew older and were worked consistently hard their maintenance needs rose.

It could be expected that a more typical figure for the period 1790-1793 would have been 1.6 million rather than 2.05 million Ton Dock Days shown in Table 4.4 but this period is dominated by two ships with unusually prolonged times in dock. The "Queen" - a second rate actually entered dock on 7 August 1789 for a large repair and did not undock until 1st October 1792, and the Barfleur entered dock for a Middling/Large Repair on 28 September 1792 and did not leave it until 18 November 1793. Whilst Barfleur's docking time is long (for that scale of repair) the Queen's is unique - being nearly twice the length of any other ship's in the period.

At the other end of the scale Victory (First Rate) entered dock on 26th March 1814 for a Middling/Large Repair and did not undock until 15 January 1816. Given that she was built in 1765 and had been in near continuous commission as a Fleet Flag Ship until the end of 1812 it is not surprising that she needed extensive work.

TABLE 4.3 - DOCK DAYS PER YEAR - BY CLASS

	DOCK DAYS/YR.	1790	1791	1792	1793	1794	1795	1796	1797	1798	1799	1800	1801	1802
A	1ST Rates	20	0	0	68	13	32	30	0	133	50	15	202	6
B	2nd Rates	385	386	369	337	23	41	137	104	15	148	157	197	379
C	3 & 4th	497	536	627	575	569	735	581	428	448	594	849	606	750
E	5th Rates	514	454	374	342	304	219	79	411	446	319	250	79	91
F	6th Rates	13	35	228	279	49	59	43	90	64	121	41	54	18
G	Minor V.	167	137	85	63	62	83	103	144	431	117	87	262	71
TABLE 4.3A	TOTAL	1596	1548	1683	1664	1020	1169	973	1177	1537	1349	1399	1400	1315

	DOCK DAYS/YR.	1803	1804	1805	1806	1807	1808	1809	1810	1811	1812	1813	1814	1815	1816
A	1ST Rates	0	13	0	67	0	0	0	52	0	169	398	431	364	14
B	2nd Rates	803	460	90	196	290	0	0	10	0	28	31	0	0	0
C	3 & 4th	596	738	970	951	484	790	719	773	797	1054	1031	1312	1091	453
E	5th Rates	163	408	659	1219	1021	788	1279	1157	952	504	418	587	694	147
F	6th Rates	116	49	157	138	69	16	162	34	263	33	113	63	36	0
G	Minor V.	200	427	145	165	397	364	362	347	399	551	495	579	508	0
TABLE 4.3B	TOTAL	1878	2095	2021	2736	2261	1958	2522	2373	2411	2339	2486	2972	2693	614

84a

FIGURE 4.12

DOCKING DAYS PER YEAR
BY CLASSES

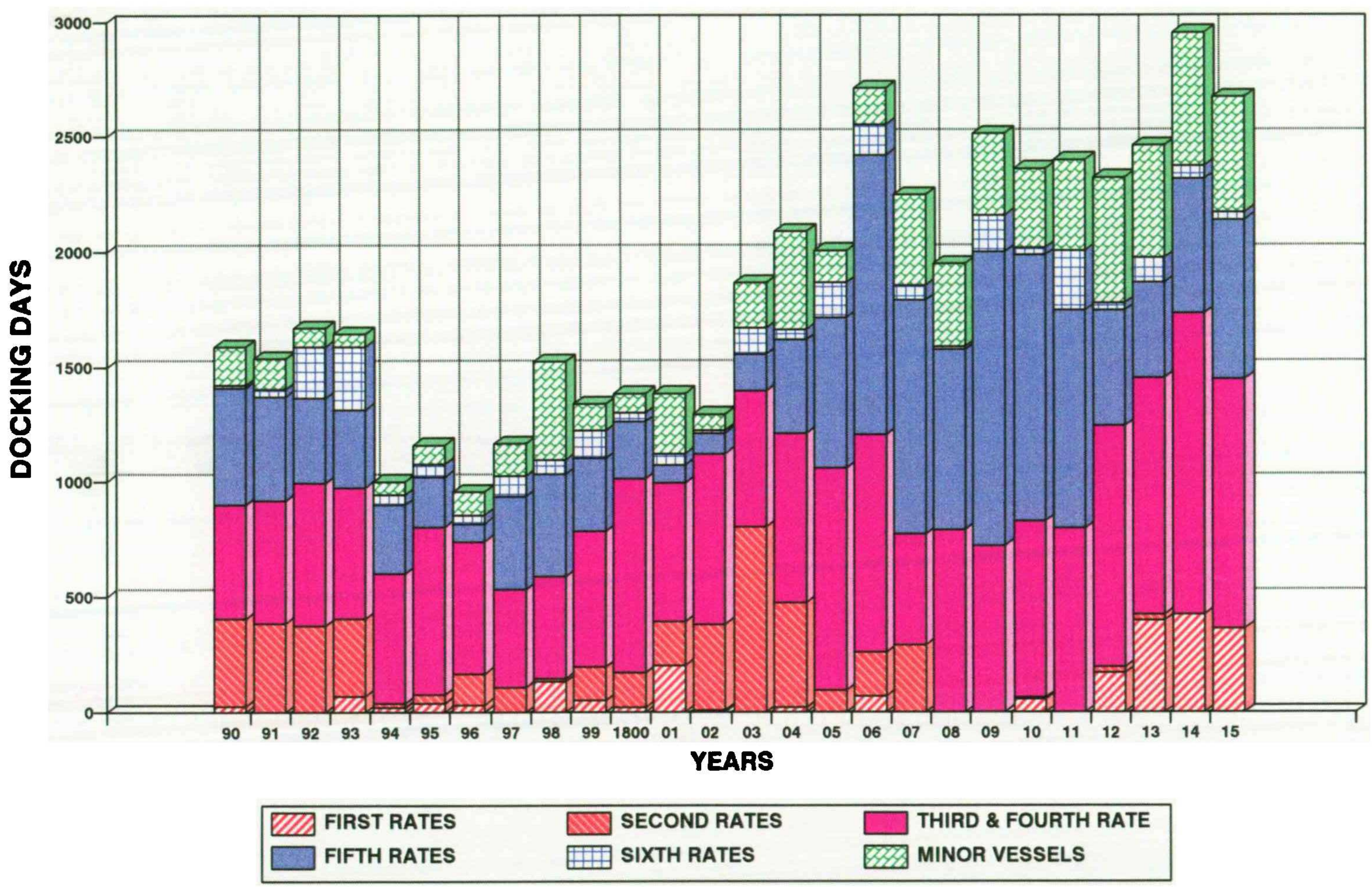


TABLE 4.4 - TON DOCK DAYS PER YEAR - BY CLASS

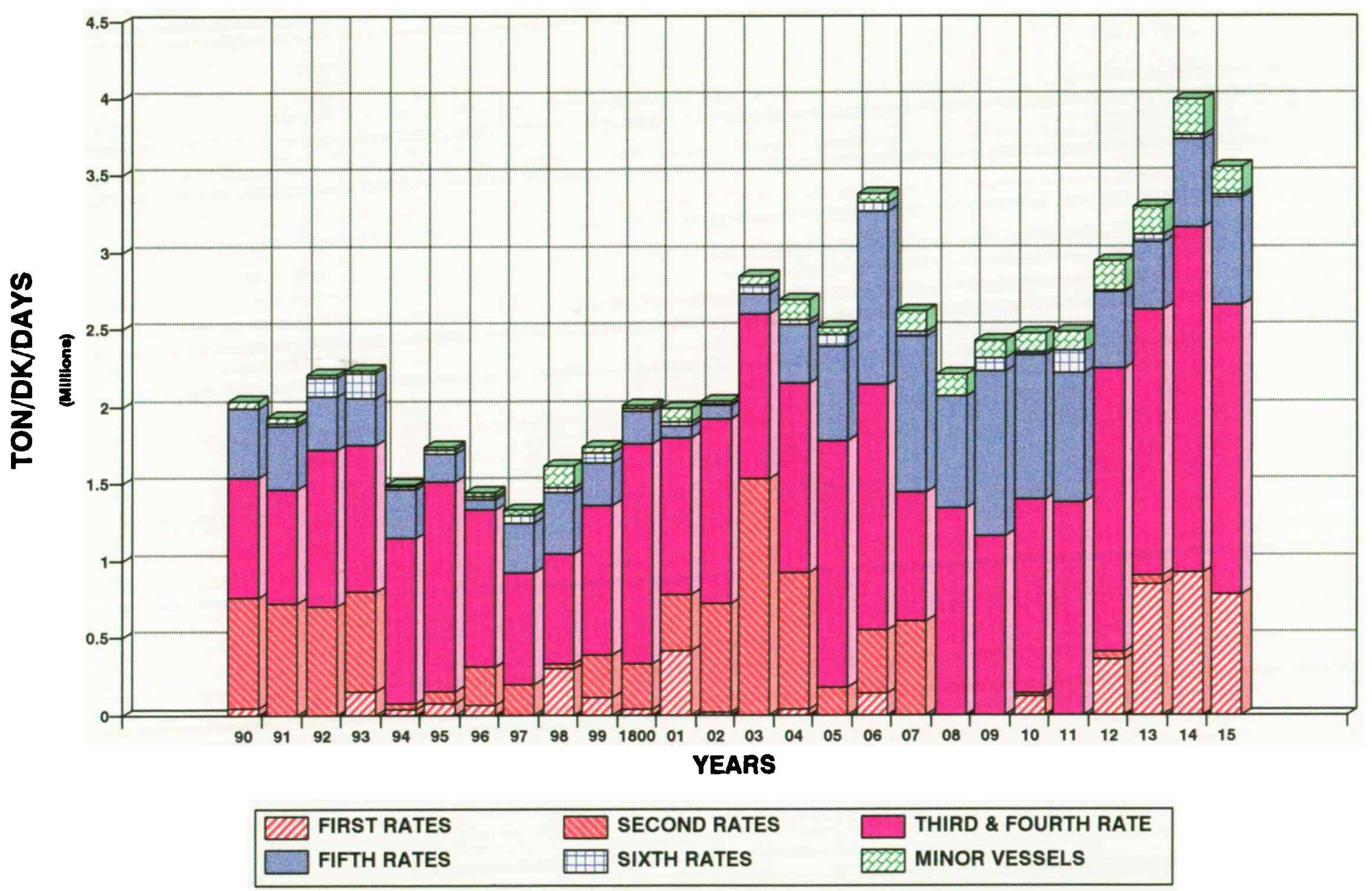
	TON DOCK DAYS PER YEAR	1790	1791	1792	1793	1794	1795	1796	1797	1798	1799	1800	1801	1802
A	1ST Rates	43240	0	0	148372	29627	70705	65790	0	303107	110080	34980	417332	12396
B	2nd Rates	721615	723546	696415	653070	44284	76839	256583	199320	28965	284472	304845	369067	709109
C	3 & 4th	785243	744499	1021286	957423	1082785	1364161	1023148	728366	720347	981860	1436647	1023867	1202633
E	5th Rates	448861	414499	345197	312075	322596	190579	73698	328852	403693	286002	211447	82446	93407
F	6th Rates	7715	19958	132504	165201	27871	33283	24642	50075	33080	71374	24256	31800	9810
G	Minor V.	49661	38287	25458	20619	18484	23628	33249	43521	143951	44654	24451	88909	20203
TABLE 4.4A	TOTAL	2056335	1940789	2220860	2256760	1525647	1759195	1477110	1350134	1633143	1778442	2036626	2013421	2047558

	TON DOCK DAYS PER YEAR	1803	1804	1805	1806	1807	1808	1809	1810	1811	1812	1813	1814	1815	1816
A	1ST Rates	0	30316	0	141437	0	0	0	122462	0	361174	841096	933365	786968	30268
B	2nd Rates	1529387	890517	175500	413756	601201	0	0	19310	0	54180	57939	0	0	0
C	3 & 4th	1072802	1238570	1602661	1597956	842341	1336195	1159036	1265671	1373891	1849473	1732898	2243118	1878898	783560
E	5th Rates	141829	383074	614102	1126574	1017511	733213	1070725	938086	839531	502932	439979	576965	700745	157584
F	6th Rates	57864	29106	80825	66337	31926	8592	90501	19462	145243	17682	56320	31971	20292	0
G	Minor V.	63619	137007	51663	60484	136536	150865	115321	131548	133152	198138	181660	229406	184709	0
TABLE 4.4B	TOTAL	2865501	2708590	2524751	3406544	2629515	2228865	2435583	2496539	2491817	2983579	3309892	4014825	3571612	971412

85a

FIGURE 4.13

TON DOCK DAYS PER YEAR
BY CLASSES



Nevertheless, looking at the growth trend across the period as a whole it is reasonable to conclude that the Ton Dock Day peak, in 1814/1815, would be better represented as 3.3M rather than the 4.01M figure shown in Figure 4.13 and Table 4.4.

The use of these figures actually decreases very slightly the range between the lowest and highest figures but otherwise does not change the pattern of figures between 1791 and 1813 at all. What it does do however is make it easier to see, in percentage terms, the true changes across the period **and gives an overall increase of around 107% from a baseline of zero in 1790.** This is shown later in Figure 4.17.1, immediately after Figure 4.17.

4.7.4. Sailings: The figures for sailings, shown in Figure 4.14 and Table 4.5, are undoubtedly distorted in 1793 - 1795 as a consequence of ships in Ordinary (Reserve) being taken out of Reserve and sent to sea just as soon as crews could be found to man them. As with Dockings the absolute number of sailings is of limited value as a measure of Dockyard output as it takes no account of the variation in size, and hence work on the differing ship classes.

4.7.5. Correlation of Dockings with Sailings: Examination of the relevant Figures and Tables for dockings and sailings demonstrates a strong correlation. On the basis that 80% of ships entering the Dockyard were docked at some time during their stay in the Yard one could initially have expected a ratio of around 100 sailings to 80+ dockings. However, when it is remembered that sailings, unlike dockings do not include ships in Harbour Service or Ordinary/Reserve (albeit these ships were docked at a lesser frequency than operational ships) a ratio much closer to parity could be looked for given that through much of the war only 70% of the Fleet was operational (Figure 3.6.2).

Table 4.6 takes four three year periods across the war and shows that within three of them the ratio of sailings to dockings was actually around 100 to 103 but by the end of the war the ratio changed to 100 to 92. However this figure disguises a significant increase in the number of dockings compared with sailings for Line (Third Rates and above). In 1795 - 97 the ratio for these ships was 100 dockings to 88 sailings and by 1812 - 1814 it had changed to 100 to 67. Most interestingly, Figure 3.6.2 (Percentages of Ships Operational at Sea) shows a figure of around 70% for Line of Battle Ships being operational in the early period and with a figure of just less than 50% in the later period.

TABLE 4.5 - SAILINGS PER YEAR - BY CLASS

SAILINGS/YEAR		1790	1791	1792	1793	1794	1795	1796	1797	1798	1799	1800	1801	1802
A	1ST Rates	1	1	0	4	0	3	1	0	1	2	1	0	0
B	2nd Rates	1	2	0	4	3	3	3	2	0	2	5	2	2
C	3 & 4th	10	7	7	16	11	21	13	13	12	14	14	16	3
E	5th Rates	10	11	3	22	17	32	14	22	20	20	20	9	12
F	6th Rates	6	6	3	8	9	3	2	4	5	4	8	3	2
G	Minor V.	8	23	10	14	12	13	13	12	17	13	15	9	10
TABLE 4.5A	TOTAL	36	50	23	68	52	75	46	53	55	55	63	39	29

SAILINGS/YR		1803	1804	1805	1806	1807	1808	1809	1810	1811	1812	1813	1814	1815	1816
A	1ST Rates	0	1	0	1	0	0	0	2	1	2	1	2	0	1
B	2nd Rates	2	1	5	0	2	1	0	1	0	1	0	0	0	0
C	3 & 4th	10	7	17	10	17	17	10	20	12	16	18	21	8	1
E	5th Rates	17	12	10	17	19	17	15	20	16	14	16	14	21	2
F	6th Rates	4	2	6	5	0	2	5	4	11	3	4	3	3	0
G	Minor V.	5	17	16	14	19	24	32	29	33	48	33	35	30	10
TABLE 4.5B	TOTAL	38	40	54	47	57	61	62	76	73	84	72	75	62	14

FIGURE 4.14

NUMBER OF SAILINGS PER YEAR BY CLASSES

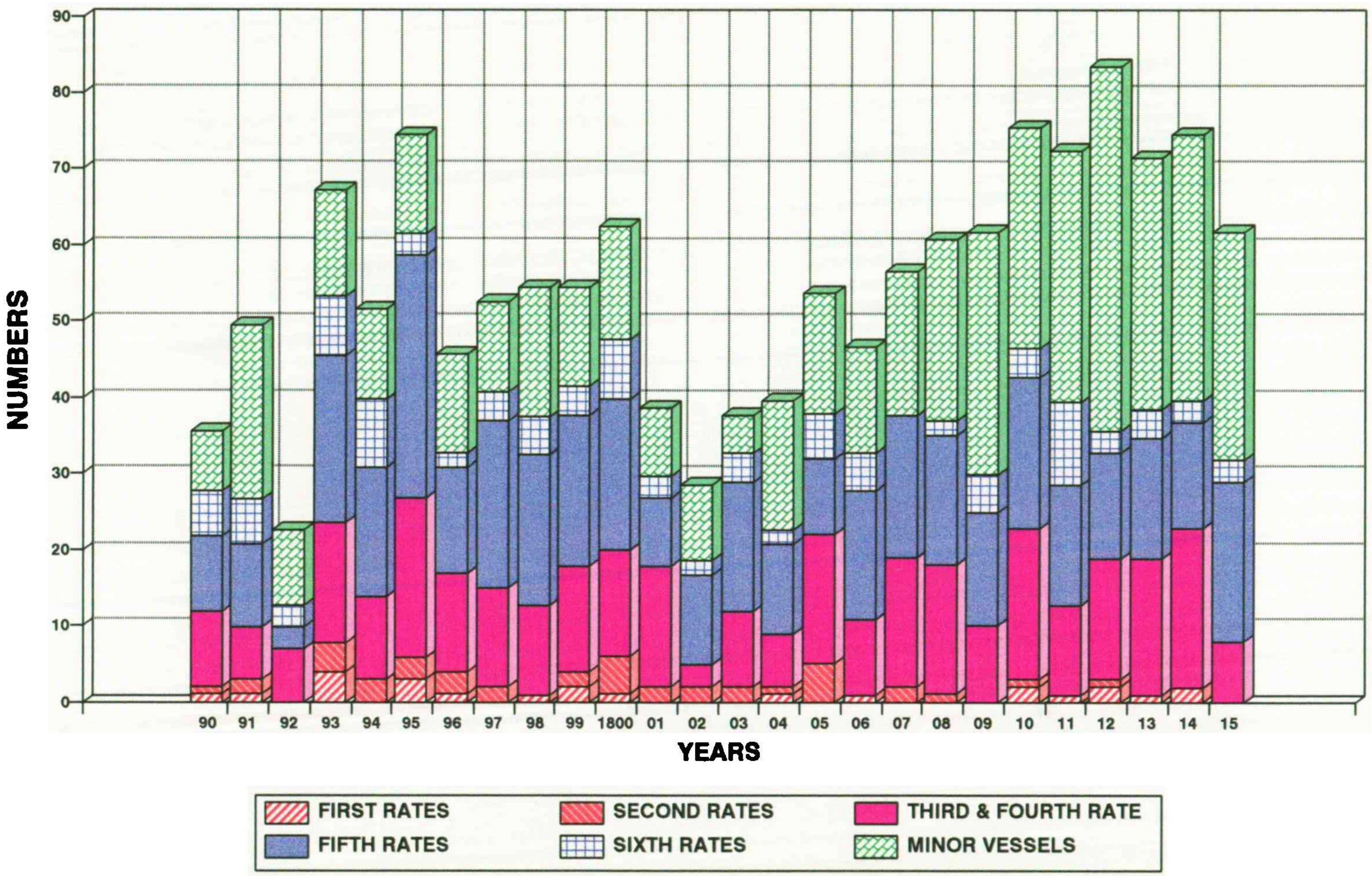


TABLE 4.6 - CORRELATION BETWEEN SAILINGS AND DOCKINGS

(As shown in four blocks across the period)

NUMBERS

SAILINGS		1795-1797	1789-1800	1809-1811	1812-1814
SAILINGS	SHIPS OF THE LINE	59	51	46	61
	FRIGATES & SMALLER	115	122	165	170
	TOTAL SAILINGS	174	173	211	231
DOCKINGS	SHIPS OF THE LINE	67	57	52	91
	FRIGATES AND SMALLER	102	108	153	160
	TOTAL DOCKINGS	169	165	205	251

RATIO - TOTAL SAILINGS/TOTAL DOCKINGS	1.03	1.05	1.03	0.92

MEAN TIME IN DOCK - ALL CLASSES - DAYS	20	26	36	31

PERCENTAGES - SHIP GROUP AS PERCENTAGE OF TOTAL

SAILINGS		1795-1797	1789-1800	1809-1811	1812-1814
SAILINGS	SHIPS OF THE LINE	34	29	22	26
	FRIGATES AND SMALLER	66	71	78	74
	TOTAL SAILINGS	100	100	100	100
DOCKINGS	SHIPS OF THE LINE	40	35	25	36
	FRIGATES AND SMALLER	60	65	75	64
	TOTAL DOCKINGS	100	100	100	100

This demonstrates two things - firstly the Portsmouth figures accord with those for the Fleet overall and secondly Portsmouth, with its 100 to 67 ratio would appear to be less involved with ships in Ordinary/Reserve than most other Yards - this is what one would expect to find in the Navy's primary refitting Dockyard.

4.7.6. Ton Sailings: The pattern of sailings shown in Figure 4.15 and Table 4.7 is distorted in 1793 and 1795 in particular by Third and Fifth Rates being taken out of Ordinary or Reserve and sent to sea with little more work being done on them, other than to put their copper on and store them, and this is supported by Figure 4.11 where the number of dockings of these classes of ship were particularly high in these years. In the second half of the war the increase in Ton Sailings owes most to the minor vessels.

There is an overall increase of 117% in Ton Sailings again from a baseline of zero in 1790, with the peak being achieved in 1810 - in line with the peak in the Fleet size and some 3 - 4 years ahead of the peak in Ton Dock Days. In looking at the Figure and Tables, from the standpoint of dockyard work load, it is only sensible to disregard the distortions in 1793 and 1795 due to ships coming out of Reserve. Overall Ton Sailings increased from 33,803 in 1790 to 73,633 in 1810 before steadying at around 63,000 for 1812 - 1814. The 10% difference between the Dockyard Output as measured by Ton Dock Days and Ton Sailings is more than accounted for by the fact that Ton Sailings, unlike Ton Dock Days, does not include any measure of time and as ships grew older their hulls needed more work.

4.7.7. Average Time in Dock: Figure 4.16 shows the average time of all Ships in Dry Dock year on year during the war and the value of the figure is in considerations of the use of the dry dock complex. The extraordinary peak in 1792 is due to just two ships - the Queen and Barfleur. These were discussed under Ton Dock Days and they can be discarded as major distortions. The peaks in 1802 - 1804 again arise from Second Rates "taking root" in dry dock during peace (the Peace of Amiens) whilst waiting to be worked on whilst the 1806 figures can only be described as a "freak" or non- representative. With these distortions accounted for there is a quite remarkable consistency across all the other years with the low figures in 1794 - 1800 being due in the first two years to mobilisation and thereafter to resource shortages - principally dry dock availability whilst the dry dock complex was being re-built. Table 4.8 shows the average dry dock times by type of ship and the large effect the few First and Second Rate ships had on the overall time in dock average.

TABLE 4.7 - TON.SAILINGS PER YEAR - BY CLASS

TON.SAILINGS/YEAR		1790	1791	1792	1793	1794	1795	1796	1797	1798	1799	1800	1801	1802
A	1ST Rates	2162	2162	0	8786	0	6720	2193	0	2279	4472	2332	0	0
B	2nd Rates	1935	3866	0	7685	5816	5613	5677	3806	0	3802	9622	3982	3932
C	3 & 4th	15218	9758	11454	23144	16928	34536	20437	21321	19219	22214	22576	25861	4822
E	5th Rates	8685	9119	2038	19012	14670	29504	12407	18666	17594	17027	17985	8484	11234
F	6th Rates	3378	3411	1741	4434	4990	1536	1188	2096	2562	2339	4734	1695	1139
G	Minor V.	2425	6286	2888	4515	3791	3997	4646	3772	5632	4695	4528	2812	3242
TABLE 4.7A	TOTAL	33803	34602	18121	67576	46195	81906	46548	49661	47286	54549	61777	42834	24369

TON.SAILINGS/YEAR		1803	1804	1805	1806	1807	1808	1809	1810	1811	1812	1813	1814	1815	1816
A	1ST Rates	0	2332	0	2111	0	0	0	4661	2138	4736	2138	4249	0	2162
B	2nd Rates	3870	1871	9825	0	4222	1935	0	1931	0	1935	0	0	0	0
C	3 & 4th	9881	16283	23201	21904	28136	28883	15497	34550	21042	27133	30563	28617	11449	6953
E	5th Rates	14384	11647	9215	16655	18772	16365	13843	18740	15458	12447	16505	13172	21063	2042
F	6th Rates	2131	1188	3358	2644	0	941	2843	2251	6030	1582	2043	1507	1564	0
G	Minor V.	1638	6266	5665	5123	6642	7560	12080	11500	11757	17041	11287	15146	13141	4639
TABLE 4.7B	TOTAL	31904	39587	51264	48437	57772	55684	44263	73633	56425	64874	62536	62691	47217	15796

FIGURE 4.15

TON.SAILINGS PER YEAR
BY CLASSES

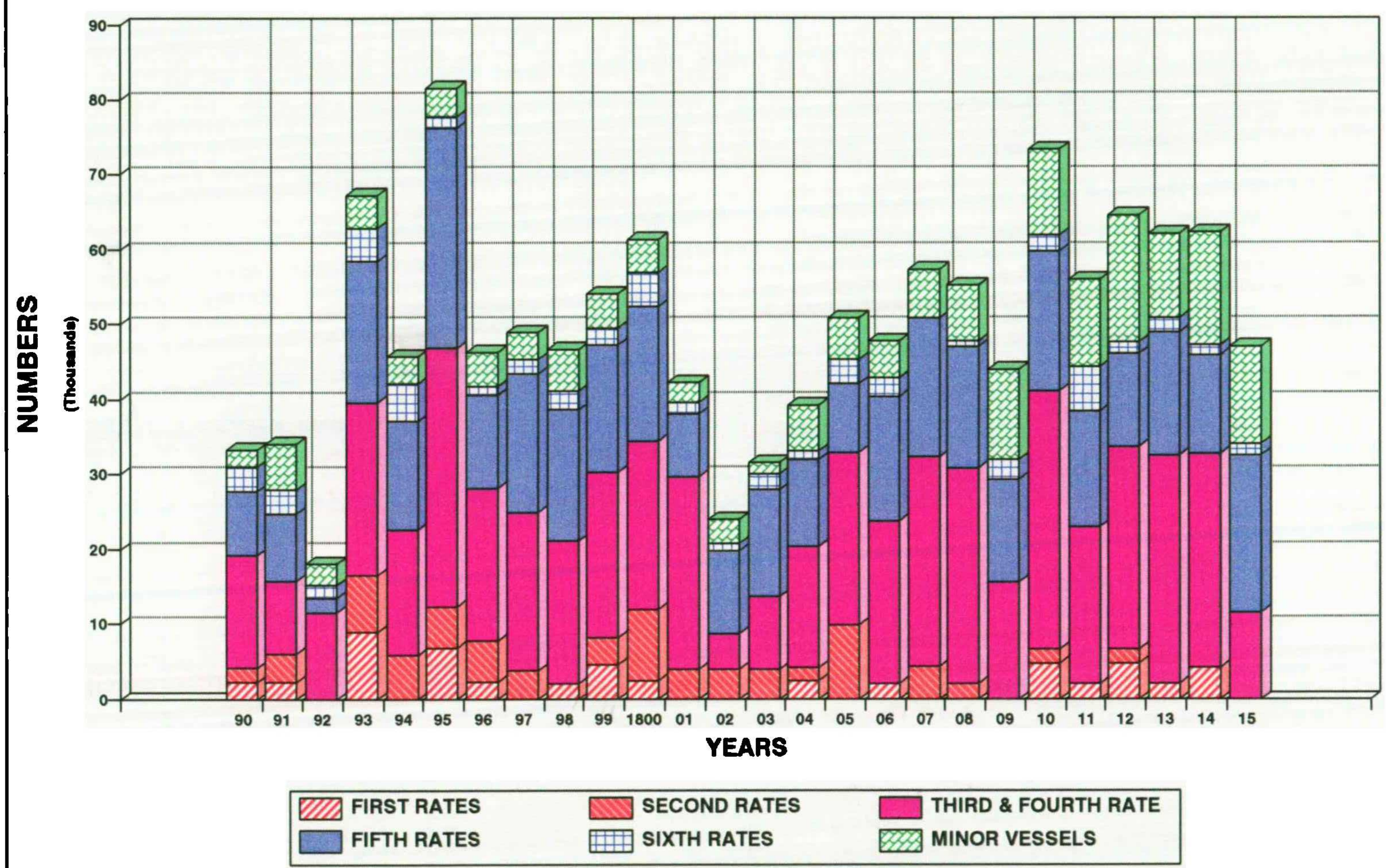


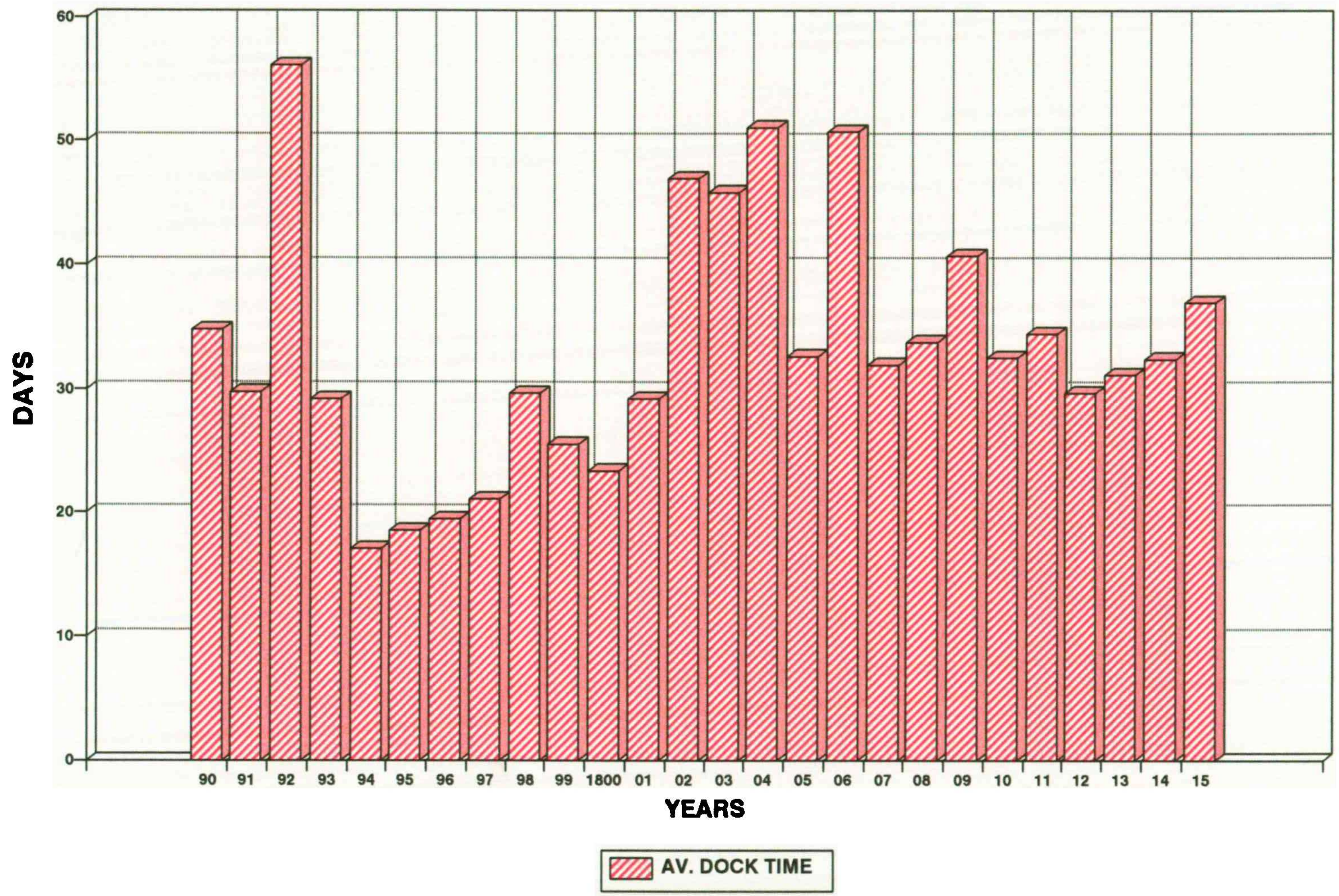
TABLE 4.8 - AVERAGE TIME IN DOCK - BY CLASS

AV.DOCK TIME		1790	1791	1792	1793	1794	1795	1796	1797	1798	1799	1800	1801	1802
A	1ST Rates	0	0	0	17	13	16	30	0	67	25	15	202	6
B	2nd Rates	193	129	185	112	8	14	46	52	15	37	52	66	190
C	3 & 4th	38	41	78	30	41	37	32	24	41	46	42	32	107
E	5th Rates	32	45	94	23	17	10	6	18	22	17	14	7	9
F	6th Rates	4	5	46	40	5	20	22	18	13	30	6	18	18
G	Minor V.	15	7	8	7	4	7	8	18	33	11	8	24	10
TABLE 4.8A	AVERAGE ALL CLASSES	34.70	29.77	56.10	29.19	17.00	18.56	19.46	21.02	29.56	25.45	23.32	29.17	46.96

AV.DOCK TIME		1803	1804	1805	1806	1807	1808	1809	1810	1811	1812	1813	1814	1815	1816
A	1ST Rates		13		67				17		56	199	108	364	14
B	2nd Rates	161	153	30	196	73			10		28	31			
C	3 & 4th	54	62	39	56	27	40	55	37	57	50	40	40	73	151
E	5th Rates	13	31	51	64	43	41	85	50	56	28	23	27	26	147
F	6th Rates	29	25	22	35	23	16	20	11	20	17	28	21	18	NIL
G	Minor V.	25	43	10	14	18	20	14	16	15	16	17	19	18	NIL
TABLE 4.8B	AVERAGE ALL CLASSES	45.80	51.10	32.60	50.67	31.85	33.76	40.68	32.51	34.44	29.61	31.08	32.30	36.89	NA

FIGURE 4.16

AVERAGE TIME IN DOCK - ALL SHIPS



4.8. Overview and Implications for the Use of Technology in the Dockyard. Figure 4.17 attempts to bring together in the one graph the yearly percentage changes, with respect to a baseline of 1790, between 1790 and 1814 in Dockings, Dock Days, Ton Dock Days, Sailings, Ton Sailings and Fleet Numbers.

The key line is that representing the growth in the fleet and if the distortions arising from the mobilisation and Peace of Amiens years are treated with some reserve it is interesting to see that the mean patterns of all the other lines generally follow that of the Fleet although they constantly lagged behind them. The Fleet figures peaked in 1810/1811 but those for Dockings, Dock Days and Ton Dock Days did not peak until 1814 - some four years later. Figure 4.17.1 is Figure 4.17 with the adjustments discussed earlier having been made in 1790 and 1813-15 - both Figures are supported by Table 4.9. Since Ton Dock Days is by far and a way the more Representative figure of the two, as far as Dockyard Work Load is concerned, a figure of 107% is used hereafter in this thesis.

The evidence from Figures 4.12 (Dock Days), 4.13 (Ton Dock Days), 4.16 (Average Time in Dock) is strong that Portsmouth Dockyard's output in the first half of the war was limited by the availability of Dry Docks and this was particularly true in the period 1795/6 - 1800 when the dry dock complex was being modernised and some docks actually had to be taken out of service for part of the period to allow this work to be completed. This view is reinforced by Figure 4.17, which shows a positive percentage increase in dockings for this period whilst Ton Dock Days shows a negative percentage change. Undoubtedly the need to restrict the work done on ships whilst they were in there in order to get ships through was a driving factor not only behind the decision to change the dry dock complex from 4 single and one double dock to 8 single docks but it also brought with it a greatly increased need for developments in filling/emptying the docks and keeping the depth of the approaches to docks adequate for the passage of ships in and out.

TABLE 4.9 - KEY FIGURES (PERCENTAGE CHANGES RELATIVE TO 1790)

Percentages(rel.to 90)	1790	1791	1792	1793	1794	1795	1796	1797	1798	1799	1800	1801	1802
DOCKINGS/YR	0.00	13.04	-34.78	23.91	30.43	36.96	8.70	21.74	13.04	15.22	30.43	4.35	-39.13
DK.DAYS/YR	0.00	-3.01	5.45	4.26	-36.09	-26.75	-39.04	-26.25	-3.70	-15.48	-12.34	-12.28	-17.61
SAIL/YR	0.00	38.89	-36.11	88.89	44.44	108.33	27.78	47.22	52.78	52.78	75.00	8.33	-19.44
TON.DK.DY/YR	0.00	-6.59	1.56	1.71	-27.16	-16.07	-29.37	-36.78	-22.19	-16.98	-2.14	-3.63	-0.90
TONSAIL/YR	0.00	2.36	-46.39	99.91	36.66	142.30	37.70	46.91	39.89	61.37	82.76	26.72	-27.91
FLT.NOs.	0.00	0.00	0.00	0.00	7.69	23.85	36.92	50.51	69.23	77.95	86.92	88.46	91.28

MODIFIED TON.DK.DY/YR	0.00	20.05	30.52	30.72	-6.39	7.87	-9.22	-18.75	0.00	6.69	25.77	23.85	27.36

TABLE 4.9A

Percentages(rel.to 90)	1803	1804	1805	1806	1807	1808	1809	1810	1811	1812	1813	1814	1815
DOCKINGS/YR	-10.87	-10.87	34.78	17.39	54.35	26.09	34.78	58.70	52.17	71.74	73.91	100.00	58.70
DK.DAYS/YR	17.67	31.27	26.63	71.43	41.67	22.68	58.02	48.68	51.07	46.55	55.76	86.22	68.73
SAIL/YR	5.56	11.11	50.00	30.56	58.33	69.44	72.22	111.11	102.78	133.33	100.00	108.33	72.22
TON.DK.DY/YR	39.35	31.72	22.78	65.66	27.87	8.39	18.44	21.41	21.18	45.09	60.96	95.24	73.69
TONSAIL/YR	-5.62	17.11	51.66	43.29	70.91	64.73	30.94	117.83	66.92	91.92	85.00	85.46	39.68
FLT.NOs.	55.90	59.74	86.15	102.31	121.79	136.15	151.03	150.26	146.15	130.26	130.51	140.00	115.64

MODIFIED TON.DK.DY/YR	79.09	69.29	57.80	112.91	64.34	39.30	52.22	56.03	55.74	86.47	106.87	107.18	107.18

TABLE 4.9B

93c

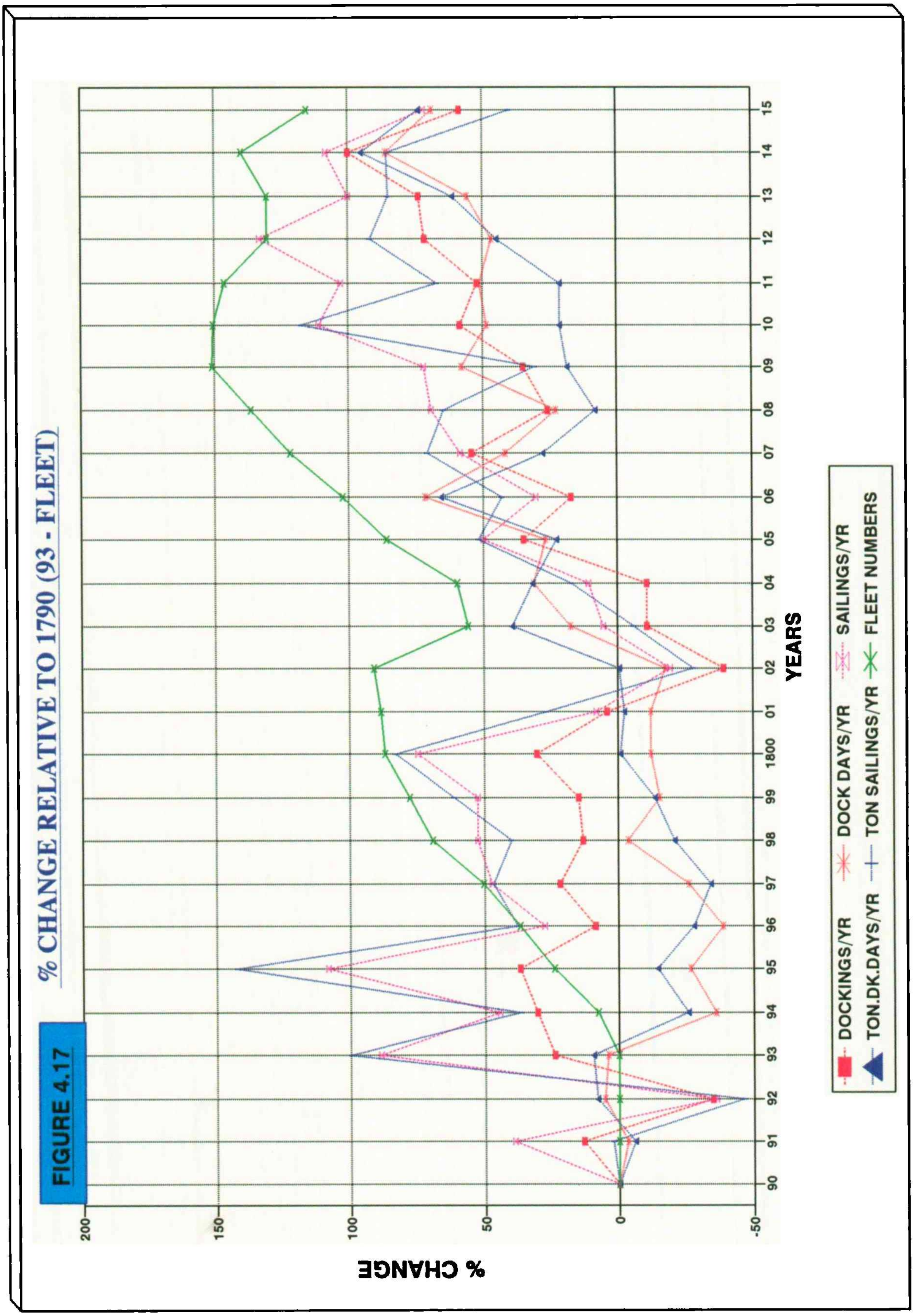


FIGURE 4.17

% CHANGE RELATIVE TO 1790 (93 - FLEET)

FIGURE 4.17.1

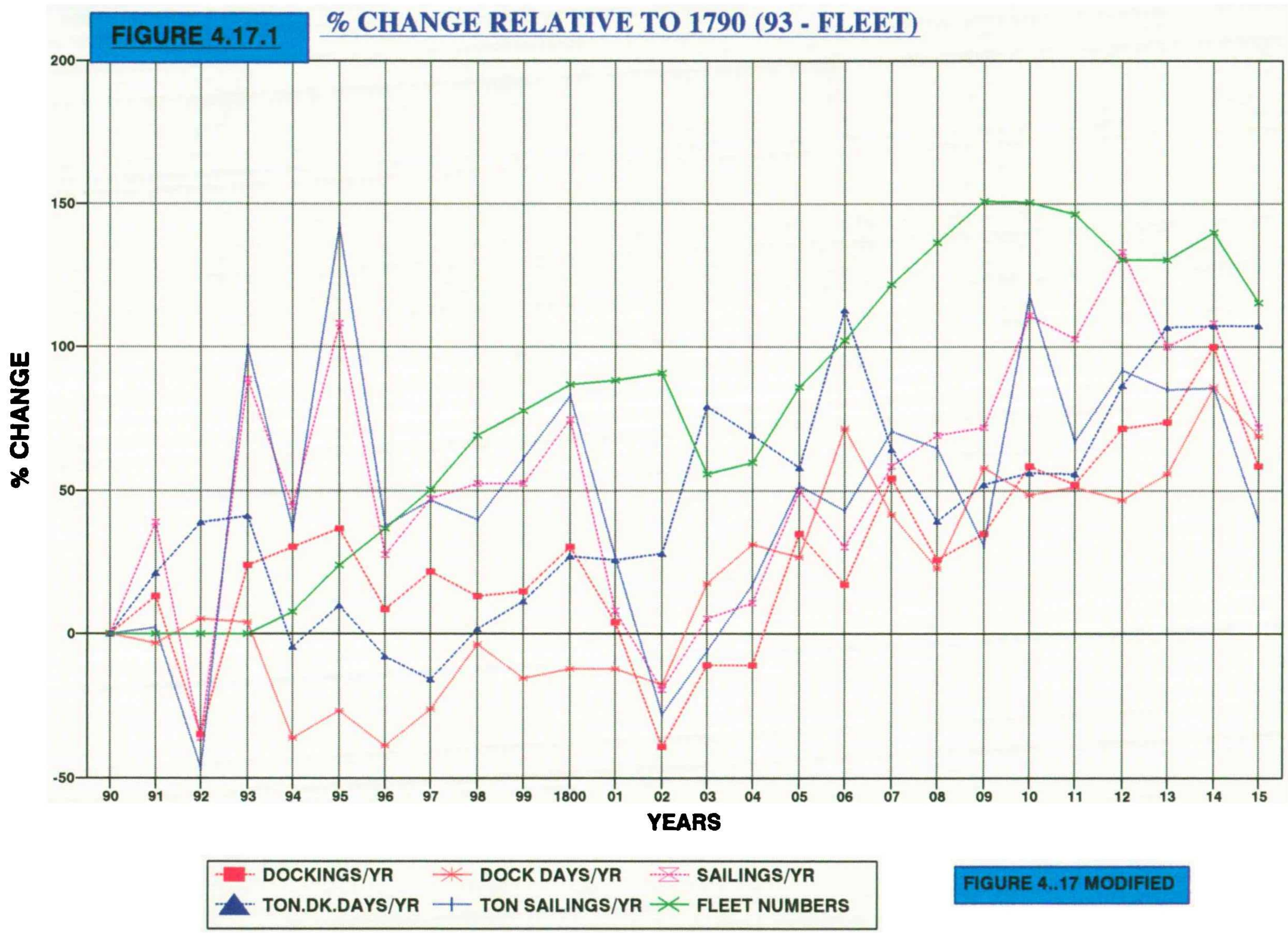


FIGURE 4..17 MODIFIED

Inspection of the one thousand, eight hundred and ten individual ship records show that on the great majority of times that a ship entered dry dock her copper was taken off and replaced - of the fifty one Third & Fourth Rates who were docked between 1 January 1807 and 1 January 1810, forty nine had their copper taken off and replaced[41]. The resultant increase in the demand for copper sheeting, both new and re-processed can safely be assessed as around 100%. This meant that the Navy Board had to have a thoroughly reliable supply system for their copper sheathing or risk ships remaining in dry dock unnecessarily until further supplies arrived. It is less easy to identify the degree to which ships rigging was replaced before they sailed from the Yard but given that much of the rope and many of the blocks used were "lifed" it is reasonable to conclude that the increase in requirement in this area was not much less than 90% - again with implications for resources and manufacturing processes.

It is impossible unfortunately to enumerate the demands the refitting of ships made for new timber simply because so much timberwork was repaired rather than replaced. Few ships would not have been re-caulked to some degree or other. What can be seen from the individual records is that up to 1810 no ships were taken to pieces at the end of their service lives. They were either hulked, sold or otherwise disposed of. However from 1810 onwards the records show ships being taken to pieces so that the good timbers - particularly compass timbers could be re-used. From 1810 to 1817 the numbers of ships taken to pieces in successive years were 2,2,2,2,2,1,2 and 5. The deductions are that by this time the Dockyard had enough people available to do this work and secondly the shortages of prime timber were sufficiently acute to justify it.

What does emerge from the records is that the nature of so much of the timber work was such that it would have had to be undertaken "in situ" on the ships concerned. Either in the dry docks or at an alongside berth and much of that work was "skilled". In terms of introducing steam power to assist in this work the Dockyard was thus in a very different situation to say a cotton mill where the work could be taken to the power source.

1. P.L.C. Webb, 'The rebuilding and repair of the Fleet 1783-1793', *Bulletin of the Institute of Historical Research*, (1977), 50, p.200.

2. William James, *Naval History of Great Britain*, edited by Captain Chamier, Royal Navy, R.Bentley, London, 1847, 6 volumes. Abstract 1, volume 1.

3. A.J.Holland, *Ships of British Oak*, David and Charles, Newton Abbot, 1971, page 16.

4. David Lyon, *The Sailing Navy List*, Conway Maritime Press, London, 1993, pages 104-169.

5. Ian McNeil, (ed), *An Encyclopedia of Technical History*, Routledge, London, 1990, pages 522-524.

6. Lyon, op. cit. n.4, pp.63-66, 104-105.

7. Ibid., pp.67-72, 109-115.

8. Details of both First and Second Rate numbers can be found in Table 3.1.

9. Figure 4.1, shows the Third Rate 74 gun Illustrious launched at Bucklers Hard in 1789.

10. James, op. cit. n.2, v.1-6, Abstracts of ships and vessels belonging to the Royal Navy, Nos. 1 to 25 from 1793 to 1817.

11. Brian Lavery, *The Arming and Fitting of English Ships of War 1600-1815*, Conway Maritime Press, London, 1987, page 121.

12. Lyon, op. cit. n.4, pp.115-116.

13. Ibid., pp.77-79.

14. Edward Brenton, *The Naval History of Great Britain from the year 1783 to 1822*, C.Rice, London, 1823, volume 1, page 46-47.

15. Figure 4 shows the Fifth Rate 36 gun frigate Eurylas launched at Bucklers Hard in 1803.

16. James Henderson, *The Frigates*, Adlard Coles, London, 1970, pages 15-19.

17. David White, *The Frigate Diana*, Conway Maritime Press, London, 1987, page 9.

18. Lyon, op. cit. n.4, pp.XI-XV.

19. Brenton, op. cit. n.14, v.1, p.45.

20. Lyon, op. cit. n.4, pp.100-102, 149-157.

21. Ibid., p.XII.

22. Chris Ware, *The Bomb Vessel*, Anatomy of the Ship series, Conway Maritime Press, London, 1994, pages 90-91.

23. Brian Lavery, *Nelson's Navy, the ships, men and organization, 1793-1815*, Conway Maritime Press, London, 1989, page 221.

24. Slops were seamens clothing and bedding.

25. ADM/180/10, Progress book for First to Third Rates 1792-1862.

26. Lavery, op. cit. n.23, p.224.

27. ADM/180/6, Progress book for First to Third Rates 1759-1820.

28. James Dodds and James Moore, *Building the Wooden Fighting Ship*, Hutchinson, London, 1984. Peter Goodwin, *Construction and Fitting of the Sailing Man of War 1600-1850*, Conway Maritime Press, London, 1987 and Brian Lavery, *The Arming and Fitting of English Ships of War 1600-1815*, Conway Maritime Press, London, 1987,

29. Dodds and Moore, op. cit. n.28, pp.47-48.

30. Figure 4.1, shows a model of the Sixth Rate 20 gun frigate Kennington building at Bucklers Hard in 1756.

31. David Steel, *The Elements and Practise of Naval Architecture*, London, 1805, reprinted by Sim Comfort Associates, 1977, page 40.

32. John E.Horsley, *Tools of the Maritime Trade*, David and Charles, Newton Abbot, 1978, pages 98 and 123.

33. Jean Boudroit, *The 74 gun Ship*, Jean Boudroit, France, 1987, Volume 3, page 18 and David Steel, *The Elements and Practice of Rigging and Seamanship*, London, 1794, reprinted by Sim Comfort Associates, 1977, volume 1.

34. Webb, op.cit. n.1, v.50, pp.194-195.

35. Roger Morriss, *The Royal Dockyards during the Revolutionary and Napoleonic Wars*, Leicester University Press, Leicester, 1983, page 28, Extract from Table 5.

36. John Fincham, *A History of Naval Architecture*, Whittacker and Co., London, 1851, First edition reprinted by Scolar Press, Aldershot, 1979, pages 112-113.

37. Morriss, op. cit. n.35, p.19, extract from Table 4.

38. ADM/180/12 and 13, Progress books for Sixth Rates and below.

39. Lyon, op. cit. n.4, p.2.

40. The origin of 94 as the divisor in this calculation is obscure. A series of five articles by William Salisbury in the *The Mariner's Mirror*, volumes 52, 53 and 54 discuss this problem.

41. ADM/180/6 and 10, Progress books for First to Third Rates.

CHAPTER FIVE
PORTSMOUTH DOCKYARD -RESOURCES

5.1. General. This chapter entitled RESOURCES examines the types and numbers of people in Portsmouth Dockyard together with the range of materials they worked with. It is therefore a review of the "inputs" to the dockyard work processes and as such it complements both the previous chapter which addressed the "output" of the Yard and the chapters which follow which explore the technologies which became available and the ways in which the Yard organised itself and used some of them in its work.

The key resources, or inputs were Money, Manpower, Materials and the Dockyard fixed facilities, especially the dry docks. As was stated earlier the first of these, Money, is a subject in its own right and is outside the scope of this thesis. In any case a study of it in this period would be made particularly difficult by the inflation which Napoleon managed to engender in the British economy with the Continental Decrees. It should however be noted that this Chapter when quoting pay or prices uses pre-decimalisation conventions with 1/3d to indicate one shilling and three pence.

In the period from 1807 the service manpower of the Royal Navy and the Royal Marines reached a figure of 130,000. This, added to a front line (Regular) Army strength of around 220,000 meant that 350,000 - or ten per cent - of the Nation's young, able bodied, male population of around three and a half million[1] were under arms at any one time and since recruiting for the Navy generally took place not that far distant from the major dockyard ports it is fair to assume that in the Portsmouth area, the figure for those under arms would have reached 20% or more. However, as Royal Dockyard personnel were considered to be an important and essential element in the defence of the Realm, under Acts of 1718 and 1750 they were forbidden to emigrate[2], and they were protected from the depredations of the Press Gang. Taken in combination the manpower of the sea-going Navy and the dockyard and its infrastructure undoubtedly made major demands on the local population.

5.2. Dockyard Labour Force. The Royal Dockyards were employers on a large scale by the standards of the eighteenth century. Portsmouth's prewar establishment of labour was about 2400 but this rose to over 4600 by 1813. Successive paragraphs attempt to illuminate, and subsequently enumerate, the various crafts and employment groupings in the Dockyard where there were five departments. Of these, three were very small, albeit powerful, and two were large and contained the vast majority of the workforce. The three small ones were what would today be called the Finance Department under the Clerk of the Cheque, the Audit Department, under the Clerk of the Survey and the third was the Stores Department under the Storekeeper. All three were staffed by clerks and since technology did not enter into their work they are not discussed further in this thesis. The two large Departments were what could be called the technical and manufacturing ones and came under the Master Shipwright and the Master Attendant respectively and this Chapter is concerned with how they were manned and the nature of the work they undertook.

Table 5.1 shows the Departmental Heads and Officers, all of whom were paid on an annual basis. Also shown are the principal grades and crafts working under the Master Shipwright and Master Attendant and paid on a daily basis. The pay rates shown were for the Midsummer quarter of 1790[3]. By uprating the £200 per year paid to the Principal Officers to approximate 1999 rates, and then applying the same conversion factor to all rates of pay, the differentials between the various grades and crafts are illustrated in modern currency. As can be seen there was a sharply divided hierarchy starting with the Dockyard Commissioner, stretching down through the Principal and other Dockyard Officers to the lesser Masters of Crafts and thence to the workforce as a whole.

As in any modern working environment, there were different levels of skills needed within the workforce. The skilled men served an apprenticeship of 7 years and worked as shipwrights, caulkers, joiners, house carpenters, smiths, ropemakers and sailmakers. Next there were those men who had not been apprenticed but needed precision of hand and eye and training for their jobs. They would have considerable knowledge and skill within their own jobs; an example of this type of worker was the sawyers. Finally, there were manual workers, with little or no skill, but valued for their muscle power and ability to turn their hands to all the multifarious jobs involved in getting ships in and out of dock and materials moved around the yard.

TABLE 5.1 - WORK FORCE - 1790 - (WITH PAY RATES)

Job	No	YEARLY £,s,d	DAILY £,s,d	= P/YR	TODAY'S EQUIVALENT
DOCKYARD COMMISSIONER	1	£500.0.0			£110,000
ADMIN & CLERICAL					
Storekeeper	1	£200.0.0			£44,000
Clerk of the Cheque	1	£200.0.0			£44,000
Clerk of the Survey	1	£200.0.0			£44,000
METAL TRADES					
Master Smith	1		3s 6d	£63.87	£14,051
Plumbers	3		2s 6d	£45.63	£10,039
Brazier	1		2s 6d	£45.63	£10,039
Founder	1		2s 6d	£45.63	£10,039
Smiths	75		1s 8d	£30.30	£6,666
SAIL MAKERS					
Master Sailmaker	1		3s 0d	£54.75	£12,045
Sailmakers	47		1s 10d	£33.58	£7,388
Riggers	148		1s 6d	£27.38	£6,024
Riggers Labourers	81		1s 1d	£19.71	£4,336
WOOD TRADES					
Master Shipwright	1	£200.0.0			£44,000
Master Caulker	1	£100.0.0			£22,000
Assistant to M Shipwt	2	£100.0.0			£22,000
Master Mastmaker	1		3s 0d	£54.75	£12,045
Master Boatbuilder	1		3s 0d	£54.75	£12,045
Master Joiner	1		2s 6d	£45.63	£10,039
Master House Carpenter	1		2s 6d	£45.63	£10,039
Shipwright	796		2s 1d	£37.96	£8,351
Caulkers	133		2s 1d	£37.96	£8,351
Blockmakers	4		2s 1d	£37.96	£8,351
Joiners	57		2s 0d	£36.50	£8,030
House Carpenters	80		1s 10d	£33.58	£7,388
Wheelwrights	2		1s 10d	£33.58	£7,388
Sawyers-Topmen	68		1s 8d	£30.30	£6,666
Sawyers-Pitmen	68		1s 4d	£24.46	£5,381
Pitch Heaters	2		1s 3d	£23.00	£5,060
Quarter Boys	13		8d	£13.87	£3,051
Oakum Boys	35		6d	£9.13	£2,009
MISCELLANEOUS					
Master Attendant	1	£200.0.0			£44,000
Boatswain	1	£ 80.0.0			£17,600
Locksmiths	2		2s 6d	£45.63	£10,039
Masons	6		2s 6d	£45.63	£10,039
Bricklayers	22		1s 8d	£30.30	£6,666
Scavelmen	76		1s 6d	£27.38	£6,024
Storehouse Labourers	29		1s 6d	£27.38	£6,024
Labourers	290		1s 1d	£19.71	£4,336
Bricklayers Labourers	21		1s 1d	£19.71	£4,336

Most of the workforce of the Yard lived locally and sons followed fathers into the Yard. Recruits had to be under the specified age limit set by the Admiralty, which settled at about 35 years[4] for most of the war. In addition, they had to be passed fit and healthy by the Yard surgeon. As there were few chances to recruit shipwrights or caulkers locally, boys were apprenticed to these crafts in the Yard. Until 1802, shipwrights were apprenticed at two levels - firstly there were those boys who were apprenticed to any suitable and deserving shipwright in the Yard and secondly boys with a reasonable standard of education whose parents could afford the necessary premiums to indenture them to the Master Shipwright. This gave them a greater level of opportunity for further advancement as the Master Shipwrights led the largest department within the Dockyard, purchased timber for the Navy and worked as draughtsmen, thus designing as well as constructing ships. Those men who subsequently became Master Shipwrights had invariably been apprenticed to Master Shipwrights themselves and had the chance to acquire the necessary wider skills. After 1802 the system changed and all boys were apprenticed to the Master Shipwright, or the Master of a Craft whilst suitable craftsmen acted as their instructors. This was because the Admiralty increased the scope of apprenticeships within the yard, to cover other crafts which had previously been able to recruit skilled men locally but could now no longer obtain the requisite numbers. As will be seen, this change of policy resulted in a major increase in apprentice numbers in the second half of the period.

In merchant yards, employment was generally for the contract in hand, and the pay was better, sometimes two to three times as much as that in the Royal yards where the labour force was paid quarterly in arrears and the men were probably permanently in debt. However, their employment was comparatively secure and many men would have been on the Dockyard strength for all their working lives. Furthermore, for men with ambition and ability there was the chance of promotion and for all the labour force there was a possibility of a small pension at the end of their working life. Most men had some kind of 'perk' particular to their craft, for example, men in the wood-based crafts were allowed to take bundles of 'chips' out of the yard. 'Chips' were pieces of wood less than 3 feet long and this practice was open to abuse. It was eventually abolished and the men received a small cash sum instead as part of their pay.

At the start of the second phase of the French Wars in 1803, recruiting to the Yard was particularly difficult as the merchant yards were offering much better pay. In addition, changes to the indenturing of apprentices meant a loss of money to many men, and the labour force had lost the right to 'chips'. Later in the war, the situation improved with changes in the administration of the Yard, one of which was to pay the labour force weekly instead of quarterly and there were much needed increases in wages, as pay scales in force at the start of the war in 1793, dated from the early eighteenth century[5].

Skilled men, particularly shipwrights and caulkers, were moved between the Yards if men were urgently needed and if it was impossible to recruit sufficient locally or if there was a short term need for more labour. For example, in 1797, 59 shipwrights from Chatham, 40 from Woolwich, 20 from Chatham and 76 from Plymouth were working in Portsmouth[6]. Similarly in 1799, 20 caulkers from Deptford and 10 from Woolwich were working in Portsmouth[7]. Surprisingly, the maritime based businesses[8] in the area such as shipbuilding and ropemaking were on a small scale, even though Portsmouth was a port of call for East Indiamen[9], and merchant convoys since it was the last practical place to put men, goods or letters from London aboard an outward bound ship.

Promotion to more responsible posts occurred within the craft structure. Master craftsmen of most crafts rose within their local Yard and they stayed at the head of their craft until they retired. However promotion to the senior position in a Yard, that of Master Shipwright, was the preserve of shipwrights and caulkers alone. On promotion to a Master Shipwright's Assistant, one of whom was also the Master Caulker, men moved between the Yards on the Thames, Portsmouth and Plymouth until their seniority and suitability made them eligible for promotion to Master Shipwright. Thereafter they moved up through the lesser to the more important Yards and for one there would be the ultimate promotion to the Navy Board and Surveyor of the Navy.

The fact that many men within a particular Yard had served apprenticeships to their particular crafts there gave rise to craft solidarity and this allowed them to delay or block changes to working practices if they so wished. It also meant that they were in a position to help and protect the weaker or older members of their craft and on occasions to demand the release of members who had been pressed into the Navy.

5.3. Contract Labour Force. A large number of the small specialist tasks like making treenails were undertaken by workers on running contracts which were renewed as necessary by warrants signed by the Dockyard Commissioner. Many of these contractors worked within the Dockyard and they were paid for goods produced rather than by the day and they also received some of the Yard 'perks' or payments in lieu like 'chip' money. For example, John Chainey who was a Treenail Mooter[10], had his warrant of 15 August 1781 renewed on 23 August 1803[11]; he finally retired in August 1814 after 41 years service when a machine for making treenails was ready to start work[12]. He was paid by the hundred foot for treenails but later he also received payment in lieu of 'chips'. The paybooks[13] record the details of payment made to the holder of the contract, but it is quite possible that these were not all one-man operations. As some may have been small businesses in their own right with several people involved. Among the contracted workers are the only two examples found of women working in the Yard. One held the contract for washing the towels used by the smiths and the other was named on the contract for making and repairing oars[14]. The biggest contracts were for the horse teams each of which consisted of four horses and one man; even at the start of the war in 1793, there were 18 on the Yard strength and by 1813 there were 39 but it must be remembered that they were used for transport and as a source of mechanical "power".

5.4. Crafts and Trades within The Dockyard. The different craft areas within the Yard can be loosely divided into those using metals, fibre, wood, and miscellaneous materials under which heading are included those involved in general labouring and the erection of buildings.

5.4.1. Metal: The largest group among the metal workers were the smiths who worked wrought iron in a forge. They were sub-divided into those who were employed in making all the small iron items used in the Yard like nails and the anchor smiths who had a more specialized task for which they were paid a small additional amount per day. Also all smiths were entitled to an allowance of beer per day[15]. In addition to the smiths there were a number of more specialist craftsmen such as plumbers, a brazier and a founder who could cast metals. Much of the equipment used by the smiths can still be found in a blacksmith's shop today.

Interestingly, despite the metal workers as a group being smaller in numbers than those in the major wood crafts, most of the metal workers were paid more per day and their numbers increased sharply as the war progressed. Metal working was a particular area where new skills were added to the Yard strength as the Metal Mills and Millwrights shop were introduced - this will be dealt with in more detail later in this thesis.

5.4.2. Fibre: Fibre was at the heart of the manufacture and fitting of rope, rigging and sails and in the Ropeyard were the craftsmen who prepared the raw material, spun the rope and finished it. Ropemaking[16] was an ancient craft where the process started with the preparation of the raw material, hemp, by the hatchellers using steel toothed combs. It was then spun by twisting the vegetable fibres together to form yarn. This was done by fastening the fibre to the hooks on a tackle board, which was then turned at a constant speed to give it an even tension as the spinners walked backward down the yard pulling the emerging yarn as they went. The resultant single stranded product was either used as twine (common string as we know it today) or it was again twisted together, or spun, to form line which was the smallest multi-stranded, or rope, product. By progressively increasing the amount of yarn in each of the strands, bigger and bigger circumference ropes were made. At the top end of the rope products were hawsers which were in fact produced by further re-iteration of the process when a number of ropes (usually three) were twisted together and the biggest of these hawsers were used as anchor cables which, in the case of a First Rate, had a circumference of 24 inches[17]. Not surprisingly the process of spinning and twisting together a number of discrete strands; be they yarns at the smaller end of the scale or ropes at the cable end of the spectrum, could make considerable demands on the physical strength of the spinners and it is noticeable from the paybooks that most of the spinners were in their twenties or early thirties.

Rope which had been used but had life remaining was re-worked and used for netting, strops and scaffolding ropes and was called twice-laid rope. Some rope, particularly that used for standing rigging, was tarred to protect it against the weather and this was done by using a capstan to pull the strands through a kettle of heated tar. Horse teams were used to work the tar house capstan for which they were paid additional money at the rate of fifteen pence per haul of yarn. Some 500-600 hauls[18] could be tarred in three months.

It is important to appreciate that a major problem with ropemaking was that the material was highly inflammable and in fact the Rope House at Portsmouth was burnt down in 1760, 1770 and again in 1776[19] and it is fair to deduce that this fire hazard was a major factor in considering where and when to introduce steam driven machinery into the ropemaking business.

Closely related to the ropemakers were the Sailmakers and Riggers who often shared a working space or loft as a large space was necessary for spreading out canvas for cutting which was done with a knife not shears or scissors. Sailmakers worked at a bench which supported the lengths of canvas being sewn and served as a resting place for their tools. The most important tools were needles but a sailmaker's palm[20] was essential to protect their hand and allow sufficient pressure to push the needle through the canvas. The 'palm' is a piece of leather with a metal 'eye' which was worn on the hand. The end of the needle rested in the 'eye' and the muscles of the arm and shoulder were used to push it through the layers of canvas. Other tools to be found on the sailmaker's bench would have included twine for sewing with holders and winders, prickers, awls and fids for making holes, mallets and stretching hooks and a horn containing wax for the twine so it passed through the canvas easily. Riggers also used benches to prepare small pieces of rigging, such as the rope strops for suspending blocks, and they had a windlass and rows of stout posts for stretching the ropes whilst their tools included cutting knives, splicing spikes and mallets.

5.4.3. Wood: Workers with wood made up the greatest number of men and crafts in the Yard. The largest group and most important in the hierarchy were the shipwrights, who built and repaired the ships, although the paybooks[21] show that shipwrights also worked in the masthouse, tophouse, boathouse and at making capstans and pumps. This suggests that they all trained as shipwrights and then learnt any additional skills required for highly specialised areas like mast-making rather than being directly apprenticed to learn mast-making.The Shipwrights were supported by Caulkers who made the hulls watertight whilst shipwrights who could no longer work in the gangs because of age or infirmity were employed as 'cabin keepers' - cabins held small quantities of ready-to-use items which were frequently required, and prevented time-wasting due to fetching items from a main storehouse.

Superficially related, but in fact a quite separate trade from shipwrights, were the Joiners who were responsible for much of the internal fitting of a ship and a third separate trade were the House Carpenters who undertook the woodwork ashore in the construction of stores, workshops, offices and the piles needed during the construction of docks - trade demarcations were very much a factor in the Dockyard's life! However all were hand-based crafts and the tools they used (Figure 5.1) were very similar and included saws, axe, chisels and gouges, augers and drills, a variety of hammers and mauls and the tool most often identified with the shipwright - the adze, which all wood trades used to some degree although there were different designs to suit the demands of particular trades. Additionally there was a variety of implements to assist with moving the large pieces of timber and these included sheers legs as well as small moveable capstans which was used for both lifting and hauling. Since the bars of these machines went straight through the capstan head, there was a limit to the amount of pressure which could be exerted on the bars before the head split. There were also a simple jack and barrel screws for holding lengths of wood and wrain staves which were used to force the steamed planking into place on the hull so that it would take up the required shape.

The "mechanical" trades at the start of the period were also wood workers and were represented by the block makers, and the wheelwrights whose products could be claimed to be the first common "engines" produced by man. Multi-sheaved blocks, when used in combination, could achieve a sixfold mechanical advantage and some blocks were greater than eighteen inches in length. At the start of the period, most of the blocks which passed through, or were used, in the yard were bought from a contractor and further discussion on this subject will be found later in the thesis. Wheelwrights were to be found in most eighteenth and nineteenth century towns and large villages, all of which needed men to make and repair wheels. In addition wheelwrights also worked as wainwrights - makers of waggons, carts and wheelbarrows - and it is reasonable to suppose that the wheelwrights in the Yard served a very similar function. Also included in the list of minor trades were the oarmakers and the coopers who made and repaired the casks all ships carried in considerable numbers.

Finally there were the essential sawyers who prepared and cut timber for use. They always worked as a two man team - see Figure 5.1.1, and were paid by the hundred foot run of timber with the money being divided between them; the more experienced topman receiving a greater amount than the pitman. Their principal tools were their saws which they sharpened themselves and they also used hooks called 'dogs' for moving and securing timber. Although timber, particularly planking, was cut by water-powered mills[22] on the Continent, the British sawyer managed to retain his right to convert timber by hand until well into the nineteenth century. Certainly this was true of Portsmouth Dockyard and as Figure 5.1.1 shows the skill is still alive today.

FIGURE 5.1.

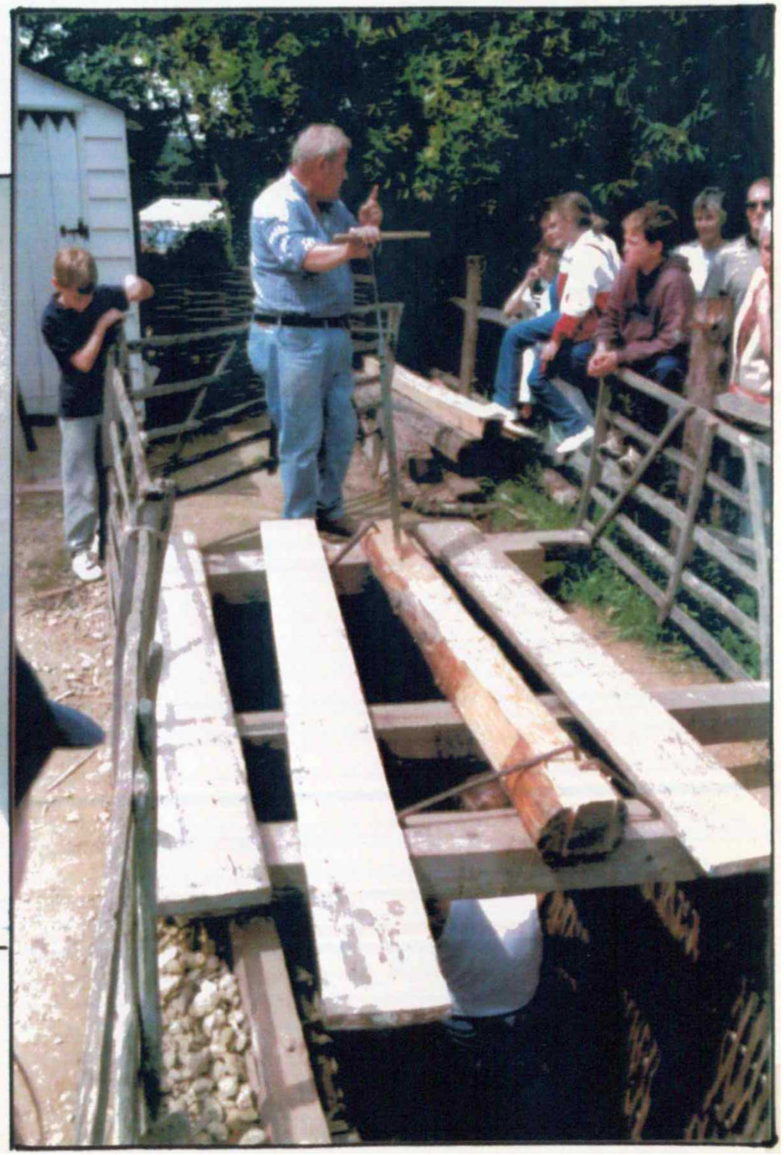


FIGURE 5.1.1

5.4.4. Miscellaneous and General Labouring: The Navy Board used contractors for large scale work to the fabric of the Dockyards, but every Yard carried on its strength men who could carry out building work, alterations or repairs. In addition to the house carpenters who have already been mentioned Portsmouth had stone masons and bricklayers together with their labourers. Major alterations to the dock area began in 1801 and whilst there is a noticeable increase in the number of stone masons employed, the numbers of bricklayers remained more stable, probably because much of this work was being done by contractors.

The second largest group of workers within the Yard after the shipwrights were the Labourers. Although they did not have a craft association like the shipwrights, there were sufficient of them to achieve the equivalent benefits of craft solidarity. It is impossible to enumerate their allocation to specific tasks which included helping to dock and undock ships, manning a range of capstans, pumps, treadmills and cranes apart from loading, unloading and moving all sorts of goods and equipment which passed through the Yard. It is also possible that they manned boats to move men and materials around the harbour and out to Spithead since there is no mention in the paybooks of any boatmen. One group of labourers whose activities can be separately identified were the labourers who worked in the Storehouses. They had a more responsible job than those of the general labourers and were paid more, the rate of 1/6d[23] a day instead of 1/1d. The other group of labourers who were paid more than the basic 1/1d per day were the scavelmen[24] who earned 1/6d a day. Their job was to keep the docks and slips clear of mud and rubbish. Their main tools, were a type of rake called a 'hummer'[25] and a skimmer formed from an iron circle with rope-yarn netting and a spade; in addition scavelmen were allowed £2 per year for boots.

5.5. The Purpose and Basis of the Dockyard Input (Workforce) Analysis. There are two reasons for undertaking an analysis of the Dockyard Workforce. Firstly it is the obvious "Representative" figure for use in an "Input" analysis of the Dockyard work process to complement the "Output" analysis in the previous Chapter and it thus provides a basis for an "Input/Output" comparison. From that it should be possible to identify areas where an increased output arises from a level input or the same output is sustained from a reduced input. Either circumstance could suggest the advantageous application of technology although care has to be taken to ensure that the real reason for the change does not arise from use of contractors or just improved working practices.

The second reason for examining the Dockyard Workforce in detail is that since "automation" did not arrive until the twentieth century the exploitation of any particular technology required an appropriate human contribution. Therefore the identification of the human input should reveal the presence of the technical application. Equally, the continuation of a manual process, despite the availability of technology, may often be revealed by payment in terms of pence per yard, per pound, etc., Evidence of either nature provides an invaluable focus in the research and examination of the application of those technologies in Portsmouth Dockyard.

The basis for the analysis of the Dockyard Workforce are the Yard paybooks[26] for the years 1790 to 1813 which show annual manpower totals for each craft/trade (and within them each pay level) in the Dockyard. Regrettably, from 1814 onwards changes in the Dockyard administration processes resulted in these sub-totalled figures being no longer recorded and to create them today would need the records of every individual man to be examined and then analysed. Fortunately a peak in the level of the Dockyard labour force was reached in 1813 and therefore the work entailed in generating the missing figures was not considered justified for the thesis. This limitation apart the Paybook figures are remarkably complete and they can safely be treated as "Representative" Input figures. They cannot be regarded as more than "representative" since material resources are involved in a full "Input" analysis and secondly the paybook figures are actually only derived from the numbers on the payroll in the second quarter of each year. Therefore they include both "Ins" and "Outs" in that three month period and hence they inevitably exceed the numbers actually at work on any particular day. As this inflation factor is constant across the period it has been ignored, since it does not significantly alter the outcome of the analysis which is primarily concerned with the pattern of year on year changes.

The Analysis addresses the manning levels in the four major work areas of Metal, Fibre, Wood and Miscellaneous. It then moves on to an overview of the workforce as a whole and the growth rates in the respective areas. These rates, expressed in percentage terms, are then associated with those for the Selected Representative "Output" figures from Chapter Four (Ton Dock Days and Ton Sailings) to permit the comparison of Output and Input growth rates. The subsequent interpretation of this comparison under the heading of Productivity takes place at the end of this Chapter following a discussion of the material resource inputs to the Dockyard.

5.6. Detail of Input (Workforce) Analysis. The Reader, when reading the detail of workforce increases/decreases, is invited to bear in mind that the overall picture emerging from the "Output" analysis was one of an increase across the period 1790 - 1815 of 107% and the overall pattern of change was illustrated in Figures 4.17 and 4.17.1. In the following paragraphs the percentage rise and fall is from a baseline of zero% in 1790.

5.6.1. Metal: The Metal trades and crafts, whose numbers are shown in Figure 5.2 together with those for their various crafts and tasks in Table 5.2, are unique amongst the Dockyard work areas in having a sustained rise across the period (with the exception of the Peace of Amiens) and the numbers grew from 81 in 1790 to 370 in 1813 - an increase of 357% - 250% above the increase in Output.

Three trades/crafts are responsible for this growth. Firstly the smiths who started the period at 75 and ended at 185. All the indications are that advances in the production of iron led to an increased use of iron products. The growing importance of the smiths was recognised in 1811 by the introduction of apprentice smiths and just two years later there were 25 of these trainees. Later chapters investigate this growing use of iron, and the advances in technology it depended on. Secondly the Metal Mills and the Millwright shop were first manned in 1806 with 6 and 5 workers respectively and by 1813 these numbers had grown to 69 and 77. The functions of and products from these plants is examined in more detail later. Thirdly there were increases in the manpower of more specialist areas such as foundry men, plumbers and a modest rise in numbers of tinmen and braziers.

5.6.2. Fibre: Figure 5.3 and Table 5.3 show the numbers for the Fibre area. This area is interesting in that the workforce suffered a sharp reduction from its 1790 numbers of 565 and, except for 1800/1801, the numbers did not return to that level until 1811 and then peaked at 680 in 1812. An increase of just 20% across the period. At first sight there is a remarkable increase in output per person but examination of the detail in Table 5.3 tells a very different story. The principal skilled workers in this area were the spinners and they started the period at 167 and finished at 201 in 1813. One of the prime supporting trades were the Line and Twine spinners and their numbers

TABLE 5.2 - METAL AREA - TRADES/CRAFTS

GRADE. A=Officer, B= SKILLED, S= SEMI SKILLED, T= MANUAL, Y=APPRENTICE

TRADE/CRAFT	GRADE	1790	1791	1792	1793	1794	1795	1796	1797	1798	1799	1800	1801	1802	1803	1804	1805	1806	1807	1808	1809	1810	1811	1812	1813
Master Smith	B	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Brazier	B	1	1	1	1	1	1	1	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1
Founder	B	1	1	1	1	1	1	1	2	2	1	1	1	1	1	2	2	2	2	2	2	3	2	2	2
Plumbers	B	3	3	3	3	3	4	3	3	3	3	3	3	3	4	4	4	4	4	4	4	5	4	6	7
Smiths	B	75	77	73	68	84	93	105	109	109	113	117	123	101	112	118	121	127	131	134	154	157	155	179	185
Tinmen	B	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1
Metal Mills	S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	29	52	62	65	65	61	68	69
Millwright Shop	S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	32	36	36	38	39	48	71	77
Apprentice Brazier	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
Apprentice Founders	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1	1	1	0	0	0
Apprentice Plumbers	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
Apprentice Smiths	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	8	25
OFFICER TOTAL		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SKILLED TOTAL		81	83	79	74	90	100	111	117	117	120	124	129	107	120	127	130	136	140	143	163	168	164	190	197
SEMI SKILLED TOTAL		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	61	88	98	103	104	109	139	146
MANUAL TOTAL		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
APPRENTICE TOTAL		0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1	1	2	12	10	27
AREA TOTAL		81	83	79	74	90	100	111	117	117	120	124	129	107	121	127	141	198	229	242	267	274	285	339	370

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FIGURE 5.2

METAL AREA - BY SKILL LEVELS
TAKEN FROM PAY BOOKS

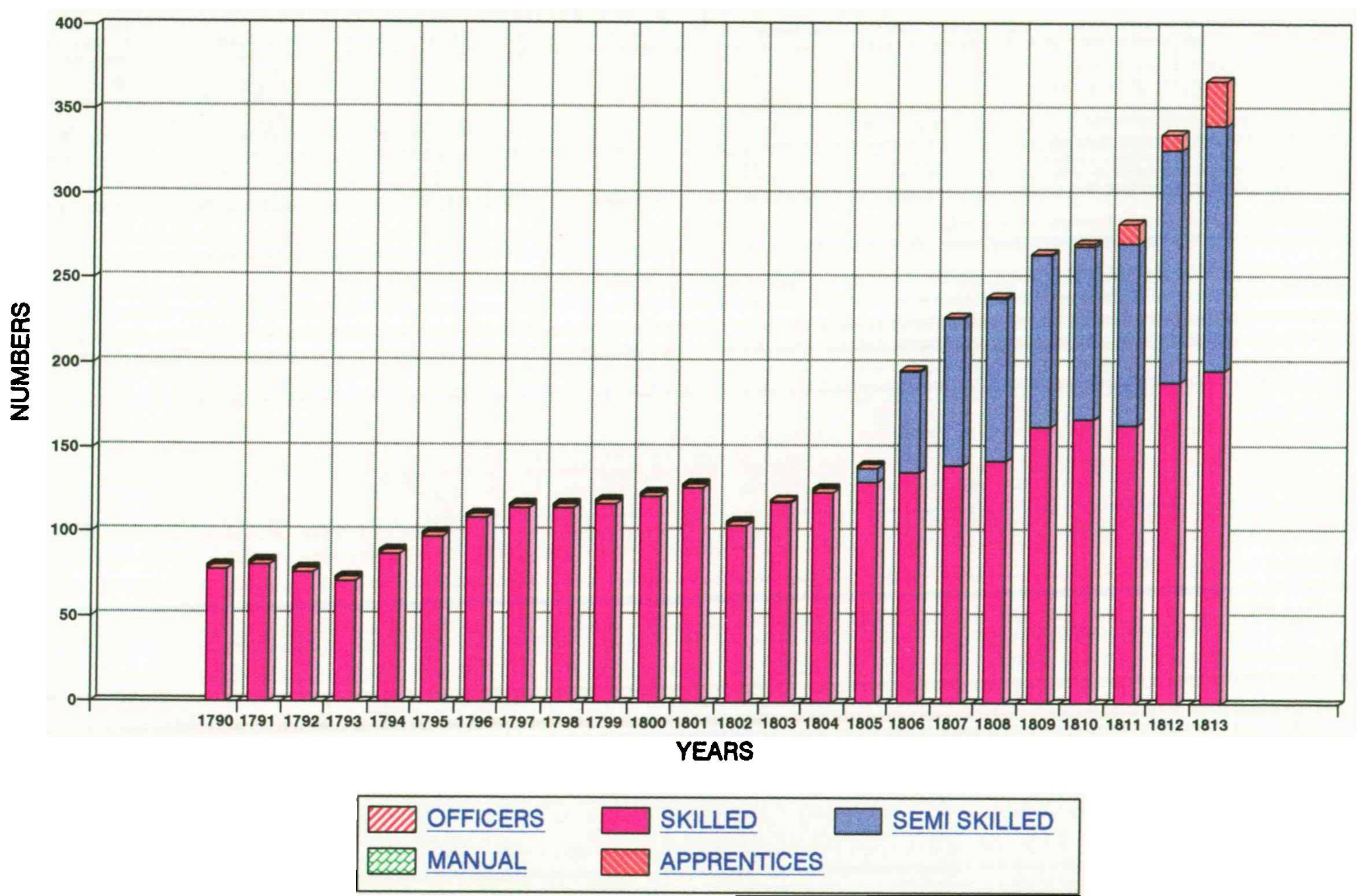


TABLE 5.3 - FIBRES AREA - TRADES/CRAFTS

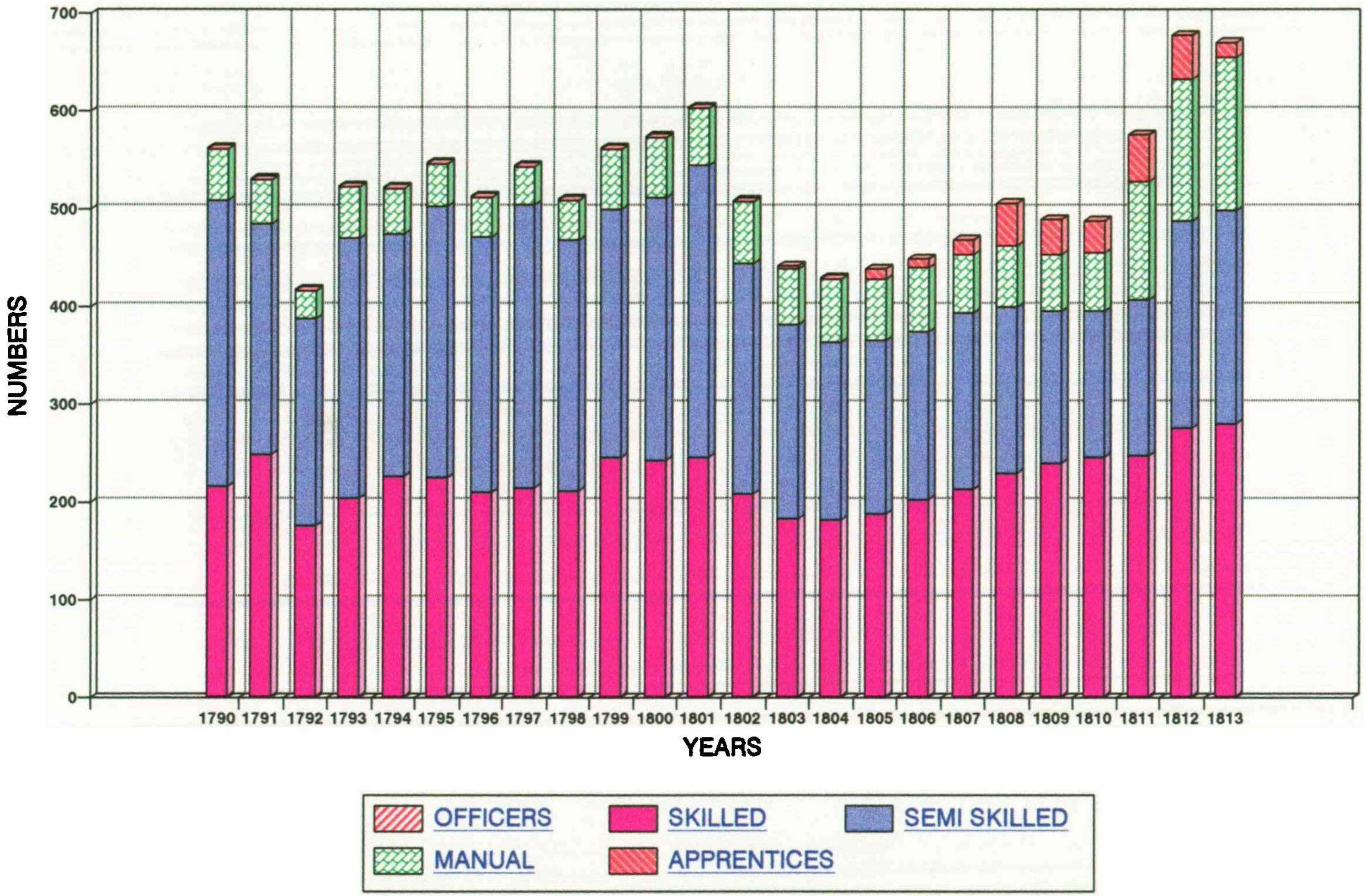
GRADE. A=Officer, B= SKILLED, S= SEMI SKILLED, T= MANUAL, Y=APPRENTICE

TRADE/CRAFT	GRADE	1790	1791	1792	1793	1794	1795	1796	1797	1798	1799	1800	1801
Clerk of the Ropeyard	A	1	1	1	1	1	1	1	1	1	1	1	1
Master Rigger	B	0	0	0	0	0	0	0	0	0	0	0	0
Master Ropemaker	B	1	1	1	1	1	1	1	1	1	1	1	1
Master Sailmaker	B	1	1	1	1	1	1	1	1	1	1	1	1
Sailmakers	B	47	81	59	55	75	60	59	60	65	67	72	80
Spinners	B	167	165	115	146	149	162	149	152	144	177	168	163
Hatchellers	S	26	26	23	27	26	26	26	26	24	28	26	26
Hemp Dressers	S	10	9	7	11	12	13	15	15	14	13	12	10
Line & Twine Spinners	S	15	14	10	12	11	8	10	10	12	11	11	9
Riggers	S	148	139	133	147	146	148	145	176	167	150	144	157
Riggers Labourers	S	81	34	29	55	39	68	52	50	28	39	62	84
Tarheaters	S	2	2	2	2	2	2	2	2	2	2	2	2
Winders	S	12	12	9	13	12	14	12	11	11	12	12	11
Houseboys	T	13	12	9	15	12	12	12	12	12	32	32	32
Ropeyard Labourers	T	24	20	11	22	18	22	18	18	18	19	16	15
Wheelboys	T	17	15	10	18	18	11	13	11	13	13	16	13
Apprentice Ropemakers	Y	0	0	0	0	0	0	0	0	0	0	0	0
Apprentice Sailmakers	Y	0	0	0	0	0	0	0	0	0	0	0	0
OFFICER TOTAL		1	1	1	1	1	1	1	1	1	1	1	1
SKILLED TOTAL		216	248	176	203	226	224	210	214	211	246	242	245
SEMI SKILLED TOTAL		294	236	213	267	248	279	262	290	258	255	269	299
MANUAL TOTAL		54	47	30	55	48	45	43	41	43	64	64	60
APPRENTICE TOTAL		0	0	0	0	0	0	0	0	0	0	0	0
AREA TOTAL		565	532	420	526	523	549	516	546	513	566	576	605

TRADE/CRAFT	GRADE	1802	1803	1804	1805	1806	1807	1808	1809	1810	1811	1812	1813
Clerk of the Ropeyard	A	1	1	1	1	1	1	1	1	1	1	1	1
Master Rigger	B	0	0	0	0	0	0	1	1	1	1	1	1
Master Ropemaker	B	1	1	1	1	1	1	1	1	1	1	1	1
Master Sailmaker	B	1	1	1	1	1	1	1	1	1	1	1	1
Sailmakers	B	63	62	60	67	67	65	70	70	80	79	82	76
Spinners	B	143	119	120	119	133	145	156	166	162	165	190	201
Hatchellers	S	22	21	22	22	21	21	21	21	21	0	0	0
Hemp Dressers	S	7	6	8	9	16	14	12	14	14	13	15	18
Line & Twine Spinners	S	8	8	8	9	7	7	7	6	7	7	7	8
Riggers	S	128	92	88	98	96	97	88	82	78	94	111	122
Riggers Labourers	S	61	61	47	31	22	33	33	23	20	44	78	68
Tarheaters	S	2	2	2	2	2	2	2	2	2	2	2	2
Winders	S	8	9	8	8	8	8	8	8	8	0	0	0
Houseboys	T	24	26	27	24	29	28	30	28	31	36	40	46
Ropeyard Labourers	T	28	22	28	28	26	20	20	20	20	73	86	90
Wheelboys	T	13	9	11	11	11	12	13	11	10	13	19	22
Apprentice Ropemakers	Y	0	0	0	11	0	0	24	16	16	30	29	0
Apprentice Sailmakers	Y	0	3	0	0	9	16	20	20	18	18	17	15
OFFICER TOTAL		1	1	1	1	1	1	1	1	1	1	1	1
SKILLED TOTAL		208	183	182	188	202	212	229	239	245	247	275	280
SEMI SKILLED TOTAL		236	199	183	179	172	182	171	156	150	160	213	218
MANUAL TOTAL		65	57	66	63	66	60	63	59	61	122	145	158
APPRENTICE TOTAL		0	3	0	11	9	16	44	36	34	48	46	15
AREA TOTAL		510	443	432	442	450	471	508	491	491	578	680	672

FIGURE 5.3

FIBRE AREA - BY SKILL LEVELS
TAKEN FROM PAY BOOKS



actually fell from 15 to 7. There were some changes in how rope craft/trades were organised and titled but again there is no evidence to support the concept of new technology being introduced into the ropemaking which took place in Portsmouth. Indeed all the evidence suggests Portsmouth increasingly relied on the other Dockyards and commercial sources to meet its growing needs.

The Riggers started at 148 and their labourers at 81 and by 1813 these numbers were down to 122 and 68 respectively. Given that rigging remained largely unaffected by technology until well into this century the evidence points firmly to the use of contractors as the reason for the drop in numbers.

On the sailmaking side numbers rose steadily (if two unusual peaks in 1791 and 1801 are ignored) from 47 in 1790 to a plateau of 99 (including 17 apprentices) in 1812 - 110% which is not far removed from the 92% for the same year in Ton Sailings (Table 4.9). There is no evidence from the paybooks to indicate any change in the terms and conditions of employment for these people and therefore it is reasonable to suggest that technology was not introduced into their working practices.

<u>5.6.3. Wood</u>: Figure 5-4 and Table 5-4 contain the detail of the biggest work area in the Dockyard. The Wood crafts and trades who numbered 1278 in 1790 and 2668 in 1813 - an increase of 109%. However this figure includes within it a rise in apprentice numbers from 48 to 336 and taking this into account, there is a remarkable correlation between the increase in Ton Dock Days (defined in Chapter 4 on page 80) and the wood workers. By far the biggest group in the wood area were the shipwrights and their numbers changed from 796 to 1428 + 210 apprentices. In total, their percentage rise was 105% and the great majority of their work was undertaken on and within ships. It comes as no surprise that there is no evidence that new technology brought a change to their working practices in the period.

TABLE 5.4 - WOOD AREA - TRADES/CRAFTS

GRADE. A=Officer, B= SKILLED, S= SEMI SKILLED, T= MANUAL, Y=APPRENTICE

TRADE/CRAFT	GRADE	1790	1791	1792	1793	1794	1795	1796	1797	1798	1799	1800	1801	1802	1803	1804	1805	1806	1807	1808	1809	1810	1811	1812	1813
Master Shipwright	A	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Assistant to M Shipwt	A	2	2	2	2	2	2	2	2	2	2	2	4	4	4	4	4	4	4	4	3	3	3	3	3
Master Caulker	A	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Master Measurer	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
Timber Master	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1
Convertors	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	2	2	2	2	2
Master Boatbuilder	B	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Master House Carpenter	B	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Master Joiner	B	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Master Mastmaker	B	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Cabin Keepers	B	10	10	10	10	11	11	10	10	10	10	10	10	12	10	10	10	10	10	10	10	10	10	10	10
Blockmakers	B	4	4	4	4	4	6	5	7	6	8	8	6	10	3	5	11	3	4	7	7	7	7	7	6
Caulkers	B	133	118	114	115	182	118	125	160	138	164	137	134	120	114	111	108	116	133	131	134	135	136	132	130
Cooper	B	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1
House Carpenters	B	80	78	77	87	78	140	112	106	106	102	123	165	145	121	107	143	144	171	174	236	242	239	232	264
Joiners	B	57	56	58	71	70	98	97	93	90	90	91	102	93	76	75	77	89	173	214	105	138	132	130	140
Oarmaker	B	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1
Shipwright	B	796	795	793	827	945	1047	1066	1139	1068	1024	1049	946	939	860	936	931	887	1144	1126	1153	1258	1256	1202	1428
Wheelwrights	B	2	2	2	2	2	2	3	3	3	3	3	4	4	3	3	3	3	3	3	3	3	3	3	3
Pitch Heaters	S	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3
Sawyers-Pitmen	S	68	68	73	74	76	87	83	85	92	94	53	99	94	67	69	70	66	66	68	82	91	94	117	121
Sawyers-Topmen	S	68	68	74	74	77	88	84	85	92	95	54	100	94	67	69	70	67	67	69	83	91	95	118	122
Wood Mills	S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	44	87	97	102	103	106	80	77	91
Apprentice Blockmakers	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Apprentice Caulkers	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	14	22	42	44	47	38	39	30	28
Apprentice House Carpenter	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2	19	21	21	21	20	29	28
Apprentice Joiners	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	4	12	16	16	16	14	19	19
Apprentice-Shipwrights	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	51	97	102	98	212	246	256	232	218	192	210
Oakum Boys	Y	35	40	37	39	39	47	36	38	36	44	43	43	42	34	35	37	34	38	41	45	45	47	46	50
Quarter Boys	Y	13	17	14	16	16	21	14	14	14	15	13	14	12	2	0	0	0	0	0	0	0	0	0	0
OFFICER TOTAL		4	4	4	4	4	4	4	4	4	4	4	6	5	5	5	5	5	6	7	7	7	8	8	8
SKILLED TOTAL		1088	1069	1064	1122	1298	1428	1424	1524	1427	1407	1427	1373	1329	1194	1254	1290	1258	1644	1671	1654	1799	1789	1722	1987
SEMI SKILLED TOTAL		138	138	149	150	155	177	169	172	186	191	109	201	190	136	140	186	222	232	241	270	290	271	314	337
MANUAL TOTAL		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
APPRENTICE TOTAL		48	57	51	55	55	68	50	52	50	59	56	57	54	92	142	153	160	323	369	386	353	339	317	338
AREA TOTAL		1278	1268	1268	1331	1512	1677	1647	1752	1667	1661	1596	1637	1578	1427	1541	1634	1645	2205	2288	2317	2449	2407	2361	2668

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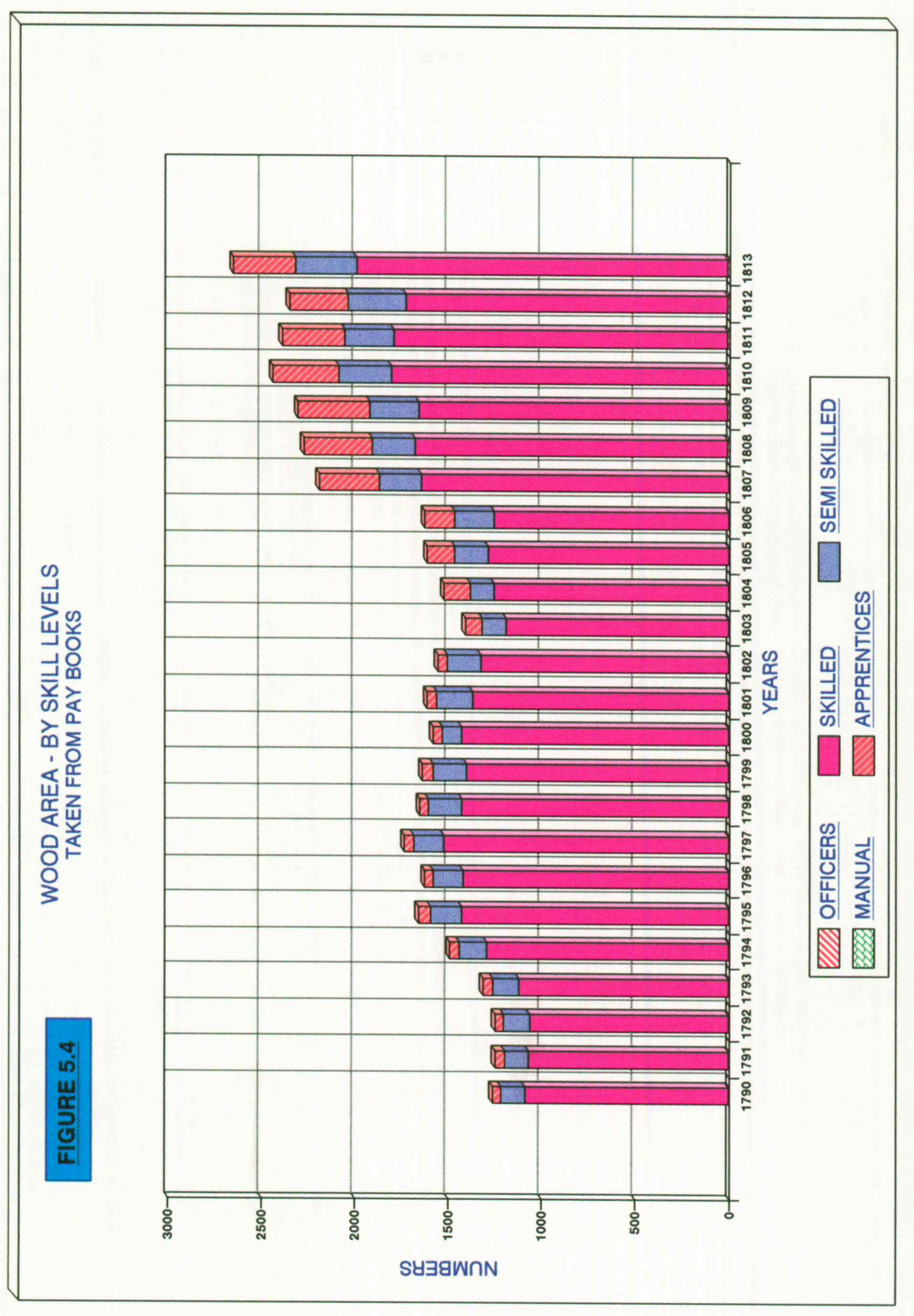


FIGURE 5.4
WOOD AREA - BY SKILL LEVELS
TAKEN FROM PAY BOOKS
NUMBERS
0
500
1000
1500
2000
2500
3000
1790 1791 1792 1793 1794 1795 1796 1797 1798 1799 1800 1801 1802 1803 1804 1805 1806 1807 1808 1809 1810 1811 1812 1813
YEARS
OFFICERS
SKILLED
SEMI SKILLED
MANUAL
APPRENTICES

In 1805 the Wood Mills started work with a workforce of 44 which rose to 100+ for 1808 - 1810 before dropping to 80 for the two successive years. These Mills, like the Metal Mills and the Millwright's Shop, are looked at in depth in a later Chapter. There were two groups of workers whose numbers might have been expected to be affected by the introduction of the Wood Mills. Firstly there were the sawyers who cut trees into planking and there were 68 pairs of them in 1790 and 95 in 1811 but there was a major rise to around 120 for the following two years. Given that the sawyers were paid by the foot of timber cut the evidence appears to point strongly towards power not having been brought into this area on a large scale during the period.

The second group whose workload might have been affected by the start up of the Wood Mills were the house carpenters and joiners who together numbered 137 in 1790 and 404 in 1813 - an increase of 195%. The cynic might be forgiven for suggesting that the apparent doubling of these people above the apparent needs of the ships was due to a major expansion in shore infrastructure like Dockyard offices, official Residences etc. However the real point is these numbers were in no way apparently reduced by products coming from the Wood Mills.

There were two very small wood crafts/trades which had a direct technical linkage. The first was that of the blockmakers who numbered just 4 in 1790 and only 7 at the end of the period and this despite the establishment of the block mills which had an eventual output of 150,000 blocks a year[27]. Morriss, in his work on *The Royal Dockyards*[28] suggest that this apparent anomaly is explained by the fact that the mills were designed not to need specialist craftsmen and they were in fact manned by using both house carpenters and labourers who, once they acquired the necessary skill to operate the machines, were paid extra allowances on top of their basic pay instead of being re-graded. The second small craft was that of the wheelwrights of whom Portsmouth Dockyard employed just two in 1790 and three in 1813. From this tiny set of records nothing emerges to suggest any change in their employment.

5.6.4. Miscellaneous: Figure 5-5 and Table 5-5 cover the Miscellaneous workforce which it is difficult to align with any one particular aspect of the work on ships. However within the area are four groups of workers who could be considerably affected by new technology.

TABLE 5 5 - MISCELLANEOUS AREA - TRADES/CRAFTS

GRADE. A=Officer, B= SKILLED, S= SEMI SKILLED, T= MANUAL, Y=APPRENTICE

TRADE/CRAFT	GRADE	1790	1791	1792	1793	1794	1795	1796	1797	1798	1799	1800	1801	1802	1803	1804	1805	1806	1807	1808	1809	1810	1811	1812	1813
Master Attendant	A	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Boatswain	A	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Master Painter	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
Locksmiths	B	2	2	2	2	2	2	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2
Bricklayers	S	22	21	20	23	22	23	22	24	23	23	24	37	33	29	31	27	27	30	40	33	32	40	39	37
Horse Teams	S	17	18	18	18	20	22	24	24	26	26	26	33	35	24	24	29	31	34	35	34	31	33	39	39
Masons	S	6	6	6	7	9	9	9	8	7	8	10	34	30	26	24	20	18	20	20	20	19	20	20	20
Painters	S	0	0	0	0	0	0	0	0	0	0	0	0	0	21	22	26	26	26	31	33	36	42	39	50
Scavelmen	S	76	75	75	76	90	104	99	101	106	112	129	136	133	100	95	87	82	81	80	80	88	122	121	122
Labourers	T	290	338	301	289	364	426	392	411	404	407	430	496	400	336	394	464	410	453	463	466	468	448	535	537
Bricklayers Labourers	T	21	19	18	23	23	25	26	23	24	22	23	48	63	44	38	28	34	35	35	33	32	39	54	47
Storehouse Labourers	T	29	29	29	29	29	37	35	36	35	36	39	38	35	30	36	35	36	36	53	40	41	40	40	40
Painters Labourers	T	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	2	2	2	2	1	2	2
Apprentice Bricklayers	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	2	2	1	2	2
Apprentice Masons	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	2	2	3	3
Apprentice Painters	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	6	7
OFFICER TOTAL		3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5
SKILLED TOTAL		2	2	2	2	2	2	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2
SEMI SKILLED TOTAL		121	120	119	124	141	158	154	157	162	169	189	240	231	200	196	189	184	191	206	200	206	257	258	268
MANUAL TOTAL		340	386	348	341	416	488	453	470	463	465	492	582	498	410	470	529	482	526	553	541	543	528	631	626
APPRENTICE TOTAL		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	4	4	4	8	11	12
AREA TOTAL		466	511	472	470	563	652	614	634	632	641	688	829	736	616	672	724	674	726	770	752	760	800	907	913

116a

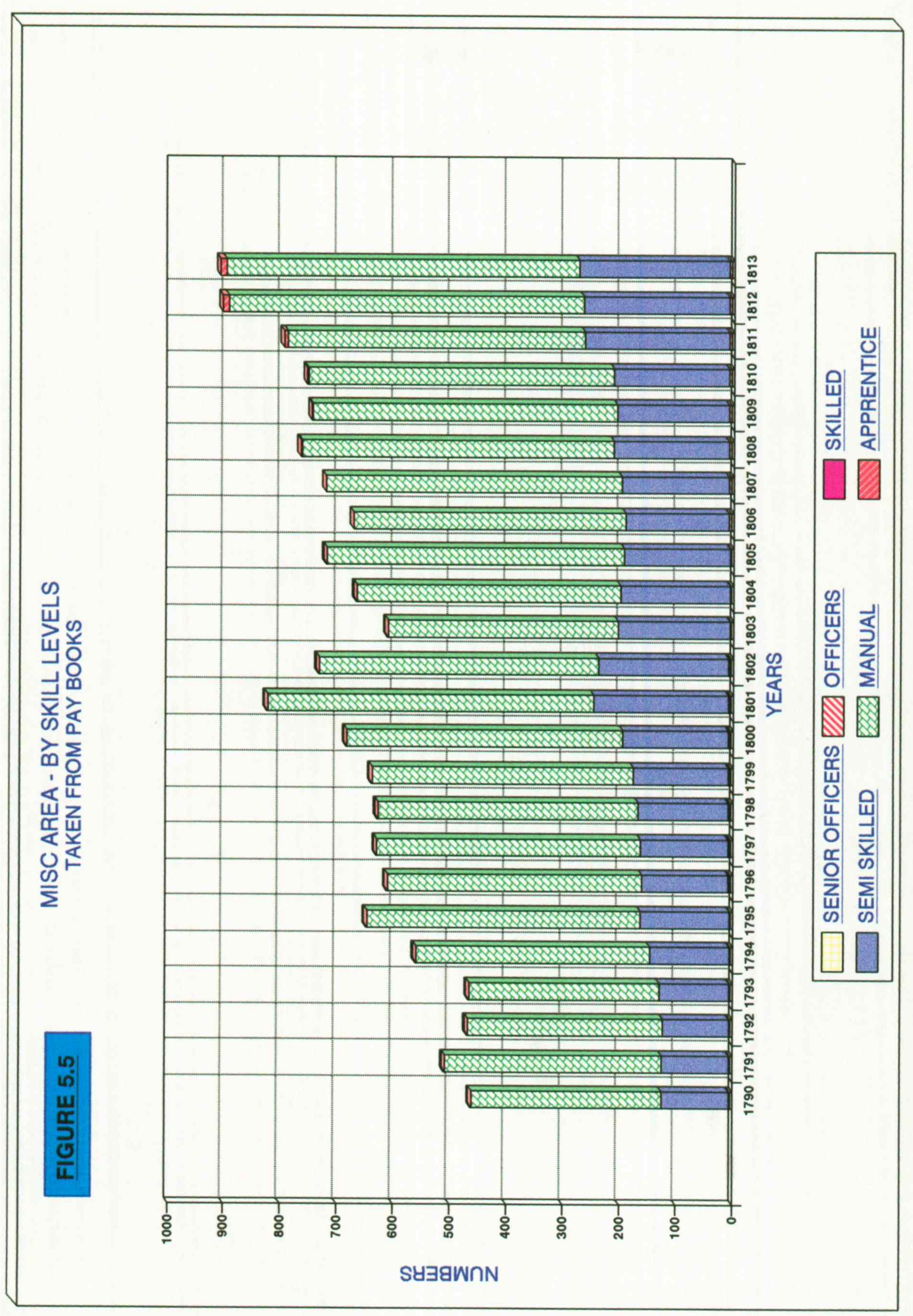


FIGURE 5.5
MISC AREA - BY SKILL LEVELS
TAKEN FROM PAY BOOKS
NUMBERS
0
100
200
300
400
500
600
700
800
900
1000
1790 1791 1792 1793 1794 1795 1796 1797 1798 1799 1800 1801 1802 1803 1804 1805 1806 1807 1808 1809 1810 1811 1812 1813
YEARS
SENIOR OFFICERS
OFFICERS
SKILLED
SEMI SKILLED
MANUAL
APPRENTICE

The first of these groups are the Horse Teams who were used not only for transport but also to "power" various machines and would be in competition with the emerging steam powered devices. In 1790 there were 17 horse teams and by 1813 this number had risen to 39; an increase of 130% which appears consistent with the growth in the Dockyard's Output and the development of its infrastructure. At least it suggests that the introduction of steam power into the Dockyard was an evolutionary rather than a revolutionary process and that its introduction was not seen as substitute for horse numbers.

In 1790 there were just 6 masons and 21 bricklayer's labourers on the Dockyard payroll. By 1813 these numbers had risen to 20 and 47 respectively giving a combined increase of 148% which supports the concept of the house carpenters and joiners increasing so much due to infrastructure development. The scavelmen were responsible for clearing the slips, the docks and the approaches to the docks and in 1790 there were 76 of them. As late as 1810 there were still only 88 of them although they, like so many other trades had a big rise in 1811 - 1813 to 122. Nevertheless the percentage rise was only 60% and this despite an increase in the number of docks from 5 (4 single, 1 double) to 8 between 1795 and 1803. It is fair therefore to suggest that this is one trade where technology did make a major difference to its manpower levels.

The last group which could have been directly affected by the introduction of technology were the general labourers who provided the "muscle" power for so much of the heaving, hauling and pumping around the yard. Their numbers in 1790 were 290 and by 1813 this had risen to 537 - a rise of 85% which is again broadly in line with the increase in dockyard output. As with the horse teams, this increase again suggests that the introduction of steam power into the Dockyard was an evolutionary rather than a revolutionary process and it was not seen as part of a deliberate policy for reducing manpower numbers.

5.6.5. The Dockyard Workforce - As a whole: Table 5.6 brings together the growth of the workforce between 1790 and 1813 under the headings of Metal, Fibre, Wood and Miscellaneous. Within these areas, the spread of skilled, semi-skilled, manual and apprentice workers are shown. Figure 5.6 illustrates the absolute growth across the work areas whilst Figure 5.6.1 shows the rate of growth in percentage terms. Well over 50% of the total workforce was employed in the Wood area which grew by some 109% - just 2% more than the overall increase in output which was assessed in Chapter 4 as 107%.

TABLE 5 6 - ALL AREAS WORK FORCE - BY SKILL AREAS

AREA & SKILL LEVEL	1790	1791	1792	1793	1794	1795	1796	1797	1798	1799	1800	1801	1802	1803	1804	1805	1806	1807	1808	1809	1810	1811	1812	1813
METAL - SKILLED	81	83	79	74	90	100	111	117	117	120	124	129	107	120	127	130	136	140	143	163	168	164	190	197
METAL - SEMI SKILLED	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	61	88	98	103	104	109	139	146
METAL - MANUAL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
METAL - APPRENTICE	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1	1	2	12	10	27
METAL - TOTALS	81	83	79	74	90	100	111	117	117	120	124	129	107	121	127	141	198	229	242	267	274	285	339	370
FIBRE - OFFICERS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
FIBRE - SKILLED	216	248	176	203	226	224	210	214	211	246	242	245	208	183	182	188	202	212	229	239	245	247	275	280
FIBRE - SEMI SKILLED	294	236	213	267	248	279	262	290	258	255	269	299	236	199	183	179	172	182	171	156	150	160	213	218
FIBRE - MANUAL	54	47	30	55	48	45	43	41	43	64	64	60	65	57	66	63	66	60	63	59	61	122	145	158
FIBRE - APPRENTICE	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	11	9	16	44	36	34	48	46	15
FIBRE - TOTALS	565	532	420	526	523	549	516	546	513	566	576	605	510	443	432	442	450	471	508	491	491	578	680	672
WOOD - OFFICERS	4	4	4	4	4	4	4	4	4	4	4	6	5	5	5	5	5	6	7	7	7	8	8	8
WOOD - SKILLED	1088	1069	1064	1122	1298	1428	1424	1524	1427	1407	1427	1373	1329	1194	1254	1290	1258	1644	1671	1654	1799	1789	1722	1987
WOOD - SEMI SKILLED	138	138	149	150	155	177	169	172	186	191	109	201	190	136	140	186	222	232	241	270	290	271	314	337
WOOD - MANUAL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WOOD - APPRENTICE	48	57	51	55	55	68	50	52	50	59	56	57	54	92	142	153	160	323	369	386	353	339	317	336
WOOD - TOTALS	1278	1268	1268	1331	1512	1677	1647	1752	1667	1661	1596	1637	1578	1427	1541	1634	1645	2205	2288	2317	2449	2407	2361	2668
MISC -SENIOR OFFICERS*	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
MISC - OFFICERS	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5
MISC - SKILLED	2	2	2	2	2	2	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2
MISC - SEMI SKILLED	121	120	119	124	141	158	154	157	162	169	189	240	231	200	196	189	184	191	206	200	206	257	258	268
MISC - MANUAL	340	386	348	341	416	488	453	470	463	465	492	582	498	410	470	529	482	526	553	541	543	528	631	626
MISC - APPRENTICE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	4	4	4	8	11	12
MISC - TOTALS	466	511	472	470	563	652	614	634	632	641	688	829	736	616	672	724	674	726	770	752	760	800	907	913
MISC - TOTALS + SNRs	470	515	476	474	567	656	618	638	636	645	692	833	740	620	676	728	678	730	774	756	764	804	911	917
GRAND TOTALS	2394	2398	2243	2405	2692	2982	2892	3053	2933	2992	2988	3204	2935	2611	2776	2945	2971	3635	3812	3831	3978	4074	4291	4627
Percentages(rel.to 90)																								
METAL % INCREASE	0	2	-2	-9	11	23	37	44	44	48	53	59	32	49	57	74	144	183	199	230	238	252	319	357
FIBRE % INCREASE	0	-6	-26	-7	-7	-3	-9	-3	-9	0	2	7	-10	-22	-24	-22	-20	-17	-10	-13	-13	2	20	19
WOOD % INCREASE	0	-1	-1	4	18	31	29	37	30	30	25	28	23	12	21	28	29	73	79	81	92	88	85	109
MISC % INCREASE	0	10	1	1	21	40	31	36	35	37	47	77	57	32	44	55	44	55	65	61	63	71	94	95
GRAND TOTAL % INC.	0	0	-6	0	12	25	21	28	23	25	25	34	23	9	16	23	24	52	59	60	66	70	79	93

118a

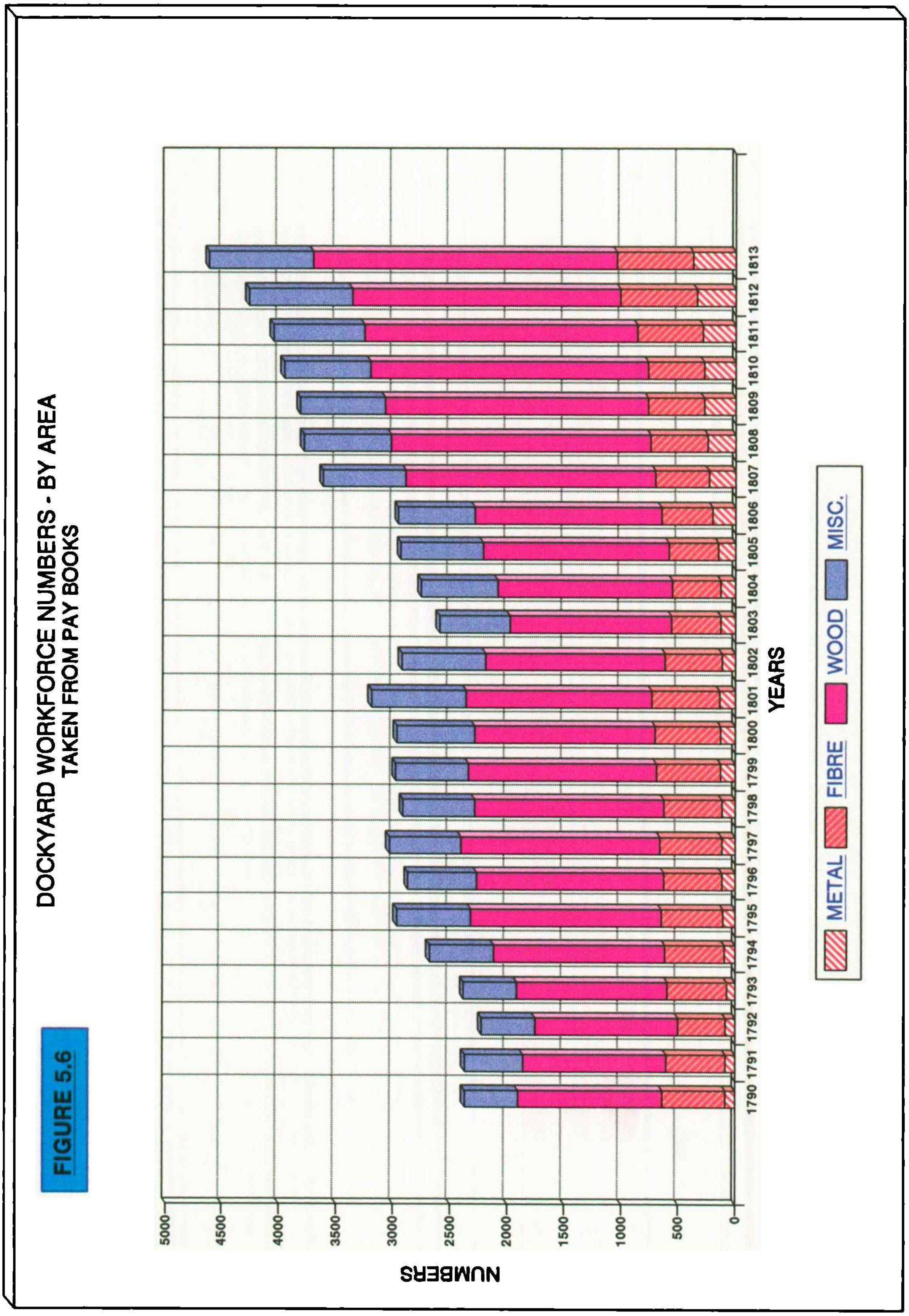


FIGURE 5.6
DOCKYARD WORKFORCE NUMBERS - BY AREA
TAKEN FROM PAY BOOKS
NUMBERS
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
YEARS
1790 1791 1792 1793 1794 1795 1796 1797 1798 1799 1800 1801 1802 1803 1804 1805 1806 1807 1808 1809 1810 1811 1812 1813
METAL
FIBRE
WOOD
MISC.

TABLE 5 6 1 - SKILL LEVELS - ACROSS ALL AREAS

SKILL LEVELS	1790	1791	1792	1793	1794	1795	1796	1797	1798	1799	1800	1801
OFFICER TOTALS	12	12	12	12	13	13	13	13	13	13	13	15
SKILLED TOTALS	1387	1402	1321	1401	1616	1754	1748	1858	1758	1776	1796	1750
SEMI SKILLED TOTALS	553	494	481	541	544	614	585	619	606	615	567	740
MANUAL TOTALS	394	433	378	396	464	533	496	511	506	529	556	642
APPRENTICES TOTALS	48	57	51	55	55	68	50	52	50	59	56	57
GRAND TOTALS	2394	2398	2243	2405	2692	2982	2892	3053	2933	2992	2988	3204
Percentages(rel.to 93)												
OFFICER % INCREASE	0	0	0	0	8	8	8	8	8	8	8	25
SKILLED % INCREASE	0	1	-5	1	17	26	26	34	27	28	29	26
SEMI SKILLED % INC.	0	-11	-13	-2	-2	11	6	12	10	11	3	34
MANUAL % INCREASE	0	10	-4	1	18	35	26	30	28	34	41	63
APPRENTICES % INC.	0	19	6	15	15	42	4	8	4	23	17	19
GRAND TOTAL % INC.	0	0	-6	0	12	25	21	28	23	25	25	34

SKILL LEVELS	1802	1803	1804	1805	1806	1807	1808	1809	1810	1811	1812	1813
OFFICER TOTALS	14	14	14	14	15	16	17	17	17	18	18	18
SKILLED TOTALS	1647	1499	1565	1610	1598	1998	2045	2058	2214	2202	2189	2466
SEMI SKILLED TOTALS	657	535	519	565	639	693	716	729	750	797	924	969
MANUAL TOTALS	563	467	536	592	548	586	616	600	604	650	776	784
APPRENTICES TOTALS	54	96	142	164	171	342	418	427	393	407	384	390
GRAND TOTALS	2935	2611	2776	2945	2971	3635	3812	3831	3978	4074	4291	4627
Percentages(rel.to 93)												
OFFICER % INCREASE	17	17	17	17	25	33	42	42	42	50	50	50
SKILLED % INCREASE	19	8	13	16	15	44	47	48	60	59	58	78
SEMI SKILLED % INC.	19	-3	-6	2	16	25	29	32	36	44	67	75
MANUAL % INCREASE	43	19	36	50	39	49	56	52	53	65	97	99
APPRENTICES % INC.	13	100	196	242	256	613	771	790	719	748	700	713
GRAND TOTAL % INC.	23	9	16	23	24	52	59	60	66	70	79	93

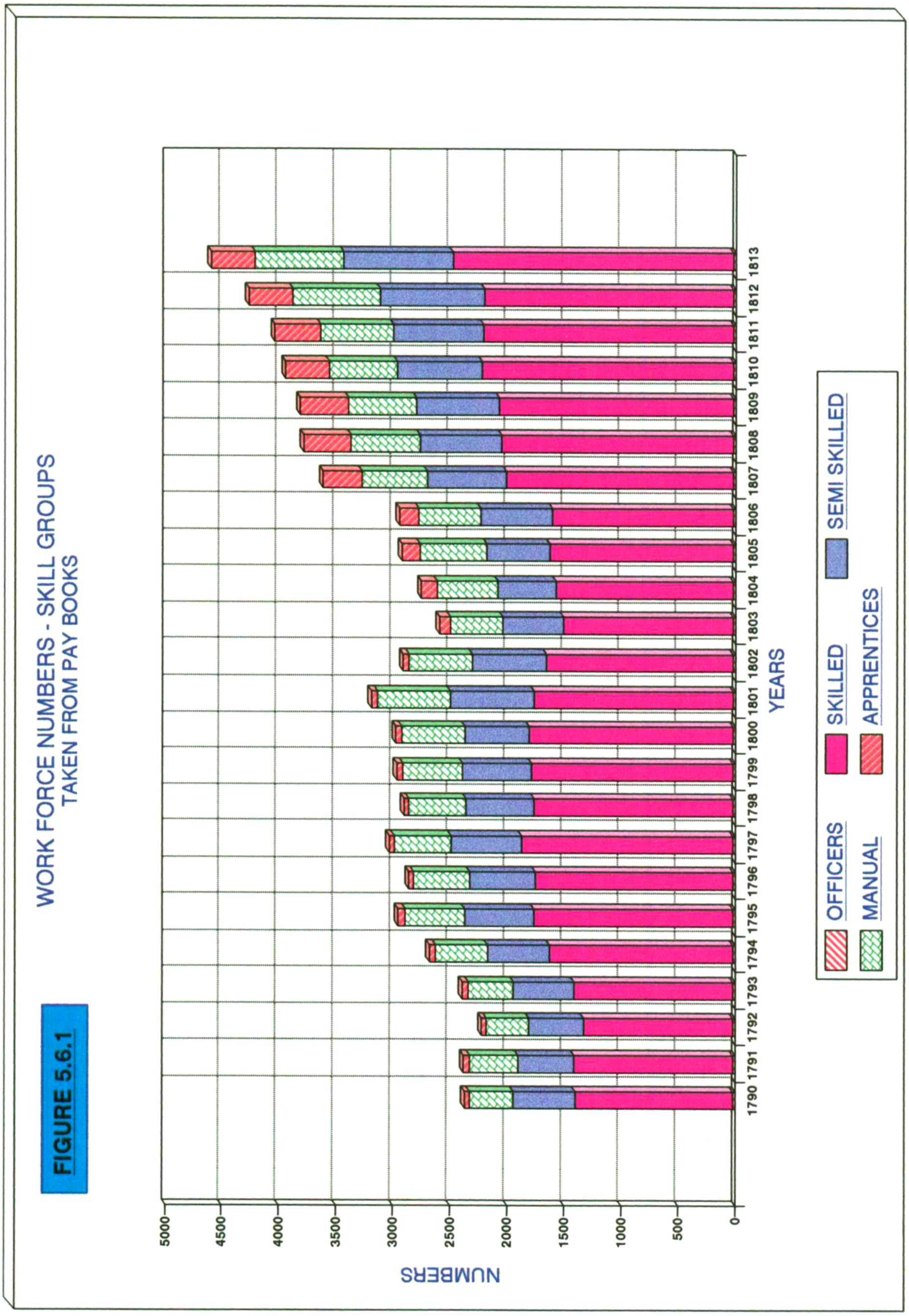


FIGURE 5.6.1
WORK FORCE NUMBERS - SKILL GROUPS
TAKEN FROM PAY BOOKS
NUMBERS
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
YEARS
1790 1791 1792 1793 1794 1795 1796 1797 1798 1799 1800 1801 1802 1803 1804 1805 1806 1807 1808 1809 1810 1811 1812 1813
OFFICERS
SKILLED
SEMI SKILLED
MANUAL
APPRENTICES

However, in percentage terms the biggest growth was in the area of metalwork where the numbers rose from 81 to 370 or a rise of 356%. The Miscellaneous area which accounted for about 20% of the workforce increased by 95% whilst the Fibre area only increased 19%.

Overall the workforce grew by 93% although the skilled and semi-skilled workers (Table 5.6.1) who made up around 75% of the total actually increased by just under 80%. It was left to the easier to recruit manual workers to increase by 99% and for the apprentices to rise from 48 to 390 - a huge rise of 713%. Much of the dramatic increase was due to re-organisation of the arrangements for such trainees in 1802 although a substantial part of the increase was also due to the acceptance that the Dockyard should train its own personnel rather than seek to attract them already trained from outside industry - a policy which had not been successful.

5.6.6. Input and Output Analysis Comparison: The principal manpower or representative input figures become more significant when viewed alongside the key figures for the Output Analysis of Chapter 4. Table 5.7 shows that by 1802, the Workforce had increased 23% and the Ton Dock Days had risen by 28% whilst the corresponding figures in 1813 were 93% and 107% which suggests a productivity increase of some 14%. Such a figure is undoubtedly an underestimate since it takes no account of the fact that by 1813, Portsmouth was producing 100% of the Navy's blocks and 66% of the total requirement for copper sheathing. This claim for increased productivity is more easily seen in Figures 5.7 and 5.7.1 where the slopes for Manpower and Ton Dock Days/Modified Ton Dock Days show the former rising more slowly than the latter and neither rising as fast as the growth in the Fleet.

5.7. Supply of Raw Materials. Regular supplies of timber and other stores were essential to the Royal Navy's existence. By the end of the eighteenth century, these supplies were purchased in both the domestic and international markets, mostly through contractors, and were consumed in huge quantities. With this duality of supply and the complexity of resource transfers between the Royal Dockyards, it has proved quite impossible, in the timescales of this thesis, to enumerate the annual rate of consumption, by Portsmouth Dockyard, of raw or indeed manufactured materials. Furthermore, given the high quality of information input on the prime Representative Input Resource - The Dockyard Workforce, it is doubtful if the quantification of material resources would add greatly to the thesis. In either event it has not been attempted.

FIGURE 5.7

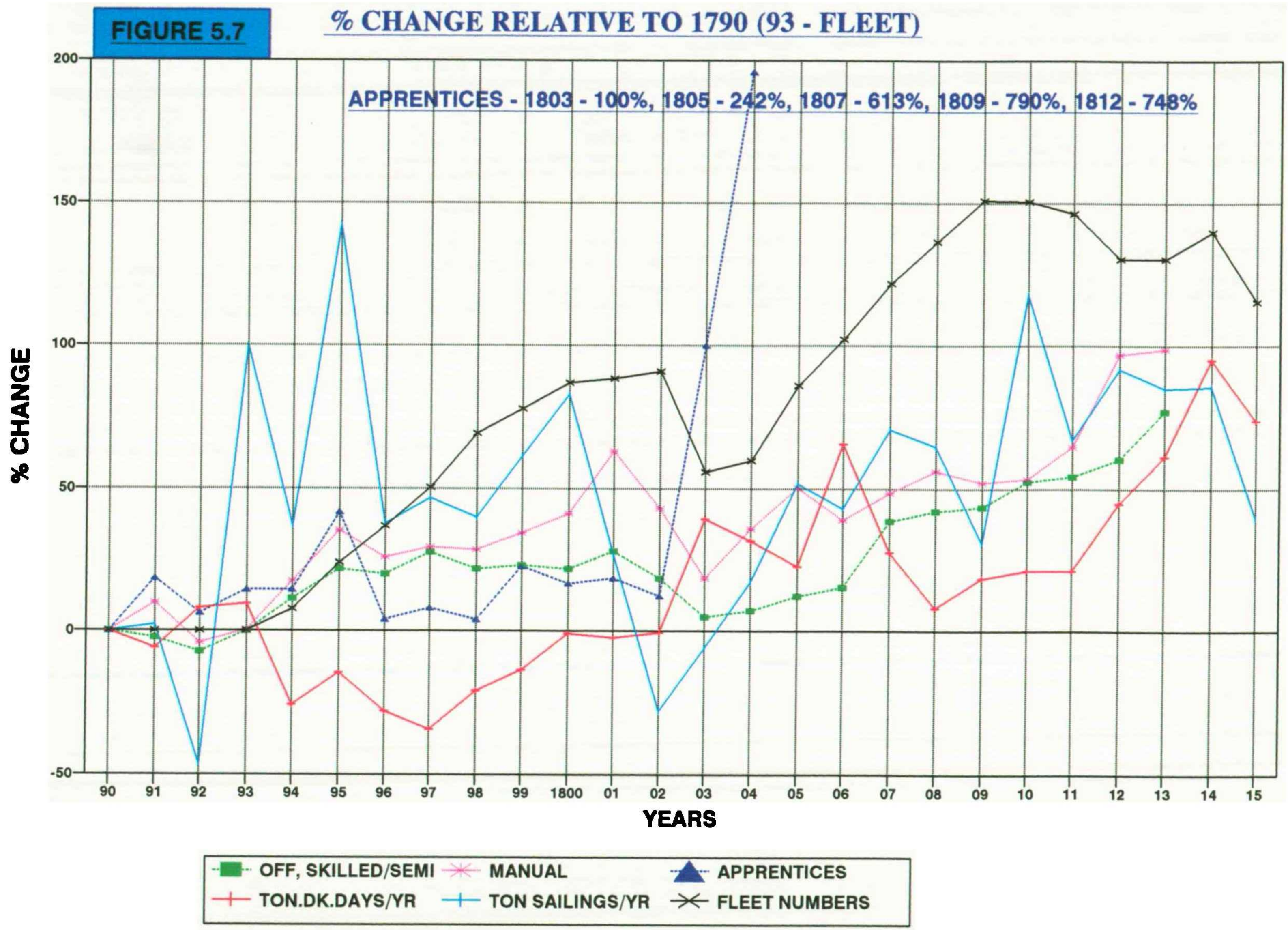

% CHANGE RELATIVE TO 1790 (93 - FLEET)
APPRENTICES - 1803 - 100%, 1805 - 242%, 1807 - 613%, 1809 - 790%, 1812 - 748%
% CHANGE
200
150
100
50
0
-50
90
91
92
93
94
95
96
97
98
99
1800
01
02
03
04
05
06
07
08
09
10
11
12
13
14
15
YEARS
OFF, SKILLED/SEMI
MANUAL
APPRENTICES
TON.DK.DAYS/YR
TON SAILINGS/YR
FLEET NUMBERS

TABLE 5 7 - OVERVIEW - KEY % FIGURES FROM INPUT & OUTPUT ANALYSIS -

Percentages(rel to 90)		1790	1791	1792	1793	1794	1795	1796	1797	1798	1799	1800	1801	1802
METAL % INCREASE		0	2	-2	-6	11	23	37	44	44	48	53	50	32
FIBRE % INCREASE	IN	0	-6	-26	-7	-7	-3	-9	-3	-9	0	2	7	-10
WOOD % INCREASE	PUT	0	-1	-1	4	18	31	29	37	30	30	25	28	23
MISC % INCREASE		0	10	1	1	21	40	31	38	36	37	47	77	67
GRAND TOTAL % INC.		0	0	-6	0	12	25	21	26	23	25	25	34	23
DOCKINGS/YR		0.00	13.04	-34.78	23.91	30.43	36.96	8.70	21.74	13.04	15.22	30.43	4.35	-39.13
DK.DAYS/YR		0.00	-3.01	5.45	4.28	-36.09	-26.75	-30.04	-26.25	-3.70	-15.48	-12.34	-12.28	-17.81
SAIL/YR	OUT	0.00	38.89	-36.11	88.89	44.44	108.33	27.78	47.22	52.78	52.78	75.00	8.33	-19.44
TON.DK.DY/YR	PUT	0.00	-6.82	8.00	9.75	-25.81	-14.45	-28.17	-34.34	-20.58	-13.51	-0.96	-2.09	-0.43
FLT.NOs.		0.00	0.00	0.00	0.00	7.69	23.85	36.92	50.51	69.23	77.95	86.92	88.46	91.28
TONSAIL/YR		0.00	2.36	-46.36	99.91	36.66	142.30	37.70	46.91	30.89	61.37	82.76	26.72	-27.91
OFFICERS/SKILLED/S. SKILLED -%		0	-2	-7	0	11	22	20	28	22	23	22	28	19
MANUAL LABOURERS -%	IN	0	10	-4	1	18	35	26	30	28	34	41	63	43
APPRENTICES	PUT	0	19	6	15	15	42	4	8	4	23	17	19	13
TOTALS		0	0	-6	0	12	25	21	29	23	25	25	34	23
MODIFIED TON.DK.DY/YR		0.00	21.30	38.80	41.05	-4.65	8.95	-7.68	-15.62	2.07	11.15	27.29	25.84	27.97

TABLE 5.7A

TABLE 5.7 - OVERVIEW - KEY % FIGURES FROM INPUT & OUTPUT ANALYSIS - MODIFIED

Percentages(rel to 90)		1803	1804	1805	1806	1807	1808	1809	1810	1811	1812	1813	1814	1815
METAL % INCREASE		49	57	74	144	183	199	230	238	252	319	357		
FIBRE % INCREASE	IN	-22	-24	-22	-20	-17	-10	-13	-13	2	20	19		
WOOD % INCREASE	PUT	12	21	28	29	73	79	81	92	88	85	109		
MISC % INCREASE		32	44	65	44	55	65	61	63	71	94	95		
GRAND TOTAL % INC.		9	16	23	24	52	59	60	66	70	79	93		
DOCKINGS/YR		-10.87	-10.87	34.78	17.39	54.35	26.09	34.78	58.70	52.17	71.74	73.91	100.00	58.70
DK.DAYS/YR		17.67	31.27	26.63	71.43	41.67	22.68	58.02	48.68	51.07	46.55	55.76	86.22	68.73
SAIL/YR	OUT	5.56	11.11	50.00	30.56	58.33	69.44	72.22	111.11	102.78	133.33	100.00	108.33	72.22
TON.DK.DY/YR	PUT	39.35	31.72	22.78	65.66	27.87	8.39	18.44	21.41	21.18	45.09	60.96	95.24	73.69
FLT.NOs.		55.90	59.74	86.15	102.31	121.79	136.15	151.03	150.26	146.15	130.26	130.51	140.00	115.64
TONSAIL/YR		-6.62	17.11	51.66	43.29	70.91	64.73	30.94	117.83	66.92	91.92	85.00	85.46	39.68
OFFICERS/SKILLED/S. SKILLED -%		5	7	12	15	39	42	44	53	55	60	77		
MANUAL LABOURERS -%	IN	19	36	50	39	49	56	52	53	65	97	99		
APPRENTICES	PUT	100	196	242	256	613	771	790	719	748	700	713		
TOTALS		9	16	23	24	52	59	60	66	70	79	93		
MODIFIED TON.DK.DY/YR		79.09	69.29	57.80	112.91	64.34	39.30	52.22	56.03	55.74	86.47	106.87	107.18	107.18

TABLE 5.7B

122a

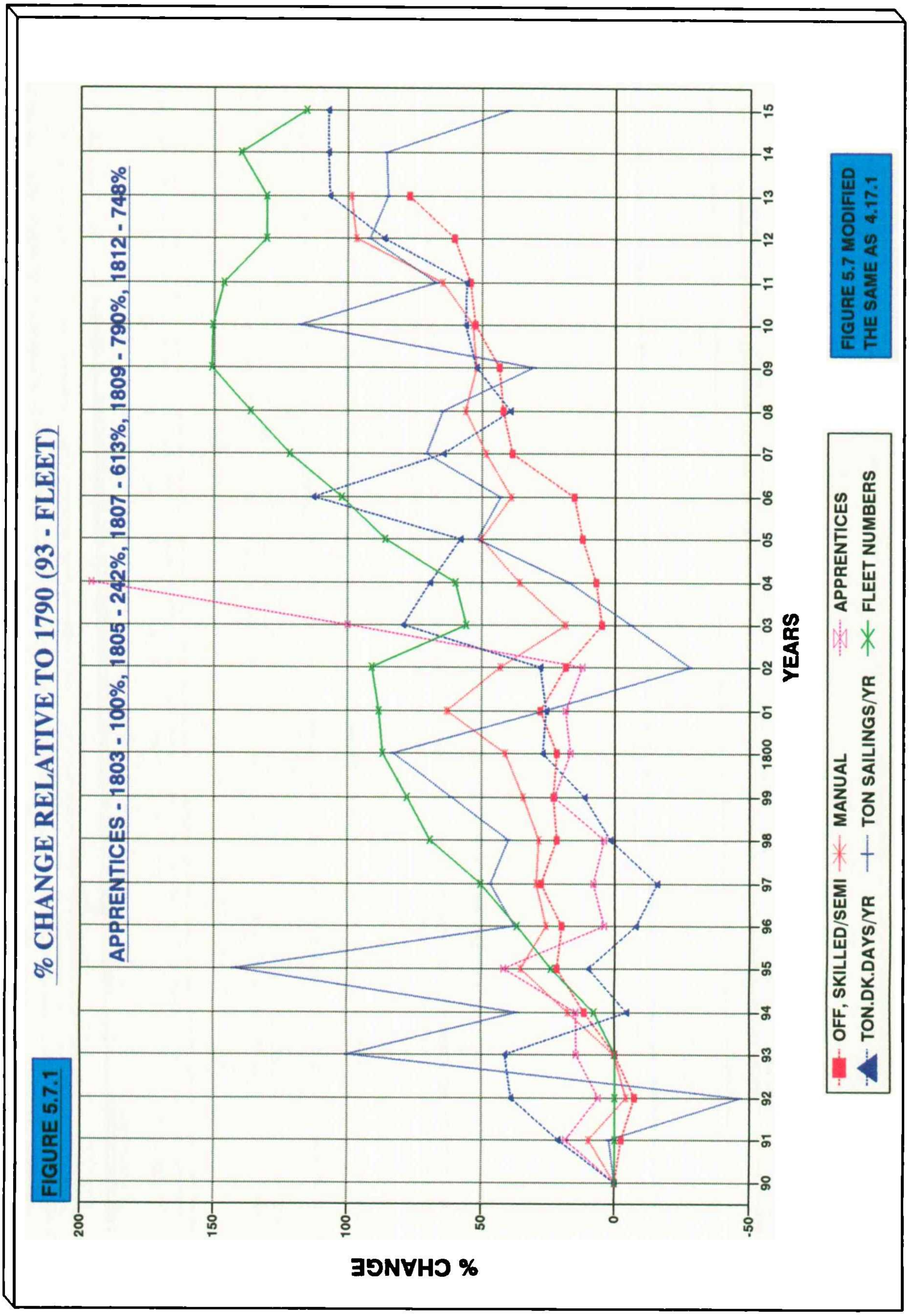


FIGURE 5.7.1
% CHANGE RELATIVE TO 1790 (93 - FLEET)
APPRENTICES - 1803 - 100%, 1805 - 242%, 1807 - 613%, 1809 - 790%, 1812 - 748%
% CHANGE
200
150
100
50
0
-50
90
91
92
93
94
95
96
97
98
99
1800
01
02
03
04
05
06
07
08
09
10
11
12
13
14
15
YEARS
OFF, SKILLED/SEMI
MANUAL
APPRENTICES
TON.DK.DAYS/YR
TON SAILINGS/YR
FLEET NUMBERS
FIGURE 5.7 MODIFIED
THE SAME AS 4.17.1

The eighteenth century had seen four wars before 1793,[29] with the subsequent need for repairs and rebuilding at the close of each war. From 1740 onwards Royal Navy ships had increased in number, size and tonnage, causing ever increasing demands on the amount of timber and supplies needed. In wartime, domestic sources of timber and naval stores were protected from export by Orders in Council and the Navy Board had the first option to acquire neutral or captured cargoes as well. However, during this period of time the Merchant Fleet was also increasing in size and tonnage and was therefore in direct competition with the Royal Navy for timber and naval stores.

Subsequent paragraphs follow the pattern established earlier in this chapter of considering raw materials under the headings of Metal, Fibre, Wood and Miscellaneous.

5.7.1. Metals: The United Kingdom's principal metal based industries (Iron, Copper, Lead, Tin and Brass) were largely supplied from national mining sources and this greatly reduced the need for overseas expenditure in this area. Only iron was "bought-in" in any quantity and that was because the naturally rich ores from Spain and Sweden had a low sulphur and phosphorus content thus making them easier for smiths to use in wrought iron work. However by the early nineteenth century British technological advances in the commercial production of both wrought and cast iron meant that the Navy became progressively less dependent on foreign supplies of iron ore.

The Royal Navy began to use Copper in increasing quantities from 1776 onwards as the fleet had sheathing fitted to its hulls. Copper ore was mined in Anglesey[30] and in Cornwall and the metal was then produced by a series of refining operations, which took place at Swansea in South Wales and in Lancashire (in both these places there were abundant wood supplies needed to fuel the refining process). The Navy purchased its copper in an already manufactured form but with the establishment of the Metal Mills the Navy Board progressively became able to re-process its old copper thus reducing its need to purchase new copper by as much as two thirds.

Other metals used in smaller quantities included Lead, which was used for the roofs and floors of the stern galleries of the bigger ships and in all warships to line the inside of the ship's magazines. Also used were Tin and Brass, the latter being an alloy of copper and zinc. Naval brass[31] was composed of 62% copper, 37% zinc and 1% tin and this mixture made the brass very resistant to corrosion from sea water.

5.7.2. Fibre: The Navy bought Hemp and Flax, which were naturally occurring large grass type plants for the manufacture of rope and canvas. By the nineteenth century, British sources of Hemp could no longer match the demands of the ropemaking and sailmaking industries and the Royal Navy resorted to importing its Hemp, often through third parties, from Russia via the ports of Riga and St. Petersburg[32] despite the edicts of Napoleon's Continental Blockade. During that Blockade, the Navy Board sought alternative sources of supply and trials were done on Hemp from Malabar[33], although there does not appear to be have been any significant contract placed in that country as a result.

5.7.3. Wood: Timber was by far the largest of the Navy's material purchases and the maintenance of adequate supplies of it was always a matter of great concern to both the Admiralty Board and the Government of the day - to build just one 74 gun ship 60 acres of one hundred year old timber was needed[34]. The Navy's position was not helped by the fact that it was in growing competition for timber with the civilian population on three fronts. Firstly, in the late eighteenth and early nineteenth century, timber was the main constructional material for buildings and the increasing population created a demand for more houses. Secondly until coal completely replaced wood or charcoal as a fuel source, which did not happen until well after the period of this thesis, timber was a primary fuel for both the domestic and the rapidly expanding British industrial market. The industrial uses of wood and charcoal included the manufacture of glass and soap and as wood ash in the manufacture of alkali by the emerging chemical industry. From the 1750s, iron smelting, formerly a large user of wood and charcoal for fuel, had been using coke instead. Thirdly, just to make the problem even worse, the best timber came from good land where as a long term crop, it faced increasing competition from annual cash food crops which were needed more and more to feed the growing populations of the towns and cities[35].

Timber was bought by the Load which was 50 cubic feet[36], and about half was lost when the timber was trimmed and cut to useable sizes. For every one ton of timber in a ship one and a half to two loads of timber needed to be bought. Timber sources, as well as having to have large quantities of suitable trees, needed to be close to water for ease of transportation to the Royal Yards. Trees were felled and transported as trimmed logs with the bark being removed and used by the tanning industry. Once cut there was a significant rejection level of processed timber due to natural flaws and poor storage. There were differing views on the best ways to season timber but an accepted practice with new ships was to frame up in green wood (usually oak) and leave the ship to season on the stocks. However this assumed that it was possible to keep a building slip non-productive for a considerable time and it is relevant that Oak needs at least three years to season, for it tends to rot if not seasoned properly.

Timbers were known under different names[37] according to their size and purpose. Compass timber was naturally curved and was used to make the frames of the ships whilst smaller pieces were used to make knees. Compass timber occurred naturally but it was also induced by deliberately bending young trees as they grew. Planking came in different sizes: thick stuff was over 4 inches thick and 12 inches wide, plank was one and a half to four inches thick and board was less than one and a half inches thick, while deals were 2-3 inches thick and only 7 inches wide.

The main types of timber used were oak, elm, and pine. Oak was considered the most suitable wood for ships hulls, as its slow growth makes it tough and durable, the best timber being between eighty and one hundred and twenty years old at felling. But oak had one major disadvantage which was that, in time, wet oak would destroy any iron bolts used to secure it. Other woods[38], red and white Pine, Teak and Pencil Cedar, were tried for ships hulls but none were particularly successful. Most of those remaining at the end of the war were taken out of service and either sold or broken up by the early 1820's. Ships' keels, stem and sternpost were made from Elm which has a close twisted grain that holds bolts well and does not rot on immersion in water. Elm was also used to make ships pumps, the shells of pulley blocks, and because it does not splinter readily, gun carriages.

All the major powers had representatives in the Baltic to buy timber and there was competition for the best stocks, as this area was considered the prime source of mast poles and deals. However, Baltic timber was expensive because of the length and cost of the journey from forest to Royal yard. Britain did have alternative sources of supply in Canada and, depending on the state of its relations with its erstwhile colony, particularly fine timber was be obtained from the New England coast of America.

5.7.4. Other Materials: Chief among the other raw materials purchased by the Navy Board were the by-products of the Scandinavian forestry industry, which included tar, turpentine, resin and pitch. Resin is the gummy extract from pine and fir and if this extract is distilled, turpentine is the result. This was used as a thinner for wax and tar and as a liniment for sprains and bruises. A by-product of the distillation process was tar, often referred to as Stockholm tar and it was used as a general preservative for both wood and rope being supplied in 32 gallon barrels called Lasts[39]. Other purchases included tallow to treat timber, wax, brimstone used in the cleaning of ships hulls and train oil made from whale, seal and fish oils.

5.7.5. Material Resource Summary: Table 5-8, which follows this page, summarises the sources of the Navy's key raw materials. The quantities of timber, hemp and other naval stores which originated from Scandinavia and the Baltic countries help to explain the importance attached to the sustained effort spent on keeping the trade routes to the Baltic open during the Continental blockade of 1806 to 1811.

5.8. Supply of Manufactured Materials. In addition to purchasing large quantities of raw materials the Royal Dockyards also procured a range of manufactured articles for use in the fleet. The biggest and most important of these were ships themselves whilst the vast majority of the other items fell under the title of Naval Stores although the dockyards also bought many items for use in their own facilities' construction and maintenance programmes.

5.8.1. Ships: As was explained in 4.4.1, under Dockyard Tasks, New Construction, it was the Admiralty Board's policy to build its ships in the Royal Dockyards where it could directly control the standards of workmanship and the quality of timber used. This policy might have been feasible in extended periods of peace, when the Navy was small and its active "at-sea" element was even smaller but it was impracticable in times of war when the size of the Fleet was greatly increased and every effort was needed to keep the maximum number of vessels at sea. In these circumstances the Admiralty was forced increasingly to turn to contract builders and outright purchase.

TABLE 5.8 - MATERIAL RESOURCE SUMMARY

MATERIAL		PRIMARY USAGES	SUPPLIED FROM WITHIN UK	SUPPLIED FROM EUROPE	SUPPLIED FROM REST OF THE WORLD
METALS	Iron - wrought	Anchors, Nails and small iron goods	Wales, North West Britain	Sweden, Spain	
	Iron - cast	Ballast	Glamorgan, Monmouth		
	Copper	Hull sheathing, Bolts	South Wales, South Lancashire		
	Lead	Pipes, Roofing	Peak District		
	Tin	Containers, Lanterns,	Cornwall		
	Brass	Bolts and Fittings	Birmingham		
FIBRE	Hemp	Rope and Cordage Canvas (heavy)	Dorset	Riga, St. Petersburg	Malabar, India - but following trials it may not have been introduced into service See page 125 for discussion
	Flax	Canvas (light)	Ireland		
WOOD	Oak	Ships hulls, Planking Treenails, Wedges	Sussex, Surrey, Hampshire, Kent, Gloucestershire.	Stettin, Memel, Danzig	New England, Canada
	Pine and Fir	Masts and Spars, Deals Rafters, Oars		Riga, St. Petersburg, Norway, Sweden, North Germany	New England, St. Lawrence valley.
TABLE 5.8A	Elm	Stem, Sternpost, Keel, Gun carriages Block shells, Wedges.	Sussex, Surrey, Hampshire, Kent, Gloucestershire		Canada, New England

MATERIAL		PRIMARY USAGES	SUPPLIED FROM WITHIN UK	SUPPLIED FROM EUROPE	SUPPLIED FROM REST OF THE WORLD
WOOD	Ash	Oars, Wedges, Rafters	Sussex, Surrey, Hampshire, Kent, Gloucestershire		
(contd)	Beech	Furniture, internal fittings, barrels	Sussex, Surrey, Hampshire, Kent, Gloucestershire		
	Teak	Ships hulls			India
	Lignum Vitae	Block sheaves, Bearings			Southern states and Central America
MISC.	Resin	Varnish,		Norway, Sweden, Baltic coast	
	Turpentine	Varnish, Thinner		Norway, Sweden, Baltic coast	
	Tar	Preservative for wood and rope		Scandinavia, Baltic coast, Archangel	
	Pitch	Coating ships hulls		Scandinavia, Baltic coast, Archangel	
TABLE	Stone	Dockyard buildings	Portland		
5.8B	Coal	Ships stoves	Newcastle		
	Train oil	Cleaning and lubricating guns Fuel for lamps	Northern Seas	Scandinavia, Baltic	

Contract building in civilian yards had been a tried and tested method since the early eighteenth century. Potential suppliers were invited to bid for contracts to build the new hulls and these contracts laid down not only the design detail but also the quantities and the quality of materials to be used. Time limits were usually specified for contract completion - the hull of a 74 could be built in three years and if the time limits were exceeded without Navy Board permission the contractor was fined. Once launched the hull was towed to the nearest Royal Yard (Portsmouth's area stretched from Exeter in the West to Hastings in the East[40]) to be coppered and fitted out. A problem with contract built ships, which became progressively worse as the war progressed and inflation set in, was that few commercial yards had sufficient capital to maintain large stocks of seasoned timber and they had to buy what was available at the time they were awarded a contract. Inevitably this led to more and more "green timber" being used in ship's hulls and some of these soon needed repair after entering service. However this was the price the Navy Board had to pay for obtaining hulls this way.

The third source of additional hulls for the Royal Navy was the "secondhand" market. The Navy purchased a number of ships originally built for the merchant fleet although these purchases tended to be concentrated on sloops, brigs and other small craft. Nevertheless they did buy several East Indiamen for use as frigates. However by far the greater number of secondhand ships were those which the previous owners lost without agreement, or payment, when they were captured and taken as prizes by the Royal Navy. After being seized, such ships were surveyed and those considered suitable for use in the fleet were bought for the Navy by the Admiralty's agents. Only if the Admiralty did not wish to purchase these vessels were they offered on the open market. There was a strong body of opinion amongst the professional officers of the Royal Navy that French built ships were actually superior as fighting ships to British ones both because they tended to be stronger round the bows and also because they were often faster that their British equivalents. Certainly many ex-French ships served in the British Fleet with real distinction and at one stage nearly a quarter of the Royal Navy's ships had been foreign built. It is worth noting in passing that this is why, even as late as the last world war, many ships of the Royal Navy, which tended to use ship's names passed down from one generation to another, had names of French origin.

5.8.2. Naval Stores: Many of the items used to fit out ships were bought ready for use. In this section just a few of such major "bought in" items are discussed and these examples have been selected because they were prime contenders for the application of new technologies which are discussed in the next chapter. Again the order in which items are considered is metal, fibre, wood and miscellaneous.

5.8.2.1. Metal: - Copper sheet was used in the Dockyard and carried in ships. The standard sheet of copper[41] was four feet long and fourteen inches wide, and there were three different weights, 32 oz, 28 oz and 18 oz per square foot. The different weights were used on particular positions on the hull, the thickest which was 32 oz/sq ft was used on the bows which took the greatest wear and behind that was a section of medium weight sheets and the hull was completed with the lightest sheets of 18 oz/sq ft. The keel was not covered in copper sheathing as that was too vulnerable to damage in that position. Instead the keel was studded or 'filled' with copper nails set very close together.

5.8.2.2. Fibre: - The process of ropemaking in the yard and the people involved have been discussed earlier in this Chapter but it is not possible to establish how much of the rope used in Portsmouth Dockyard was made there. Whilst some was procured on civil contract, a considerable amount came from within the Royal Dockyards as a whole. This is borne out by the requests for further supplies to be found in the POR\D series of letters from Portsmouth Dockyard to the Navy Board. In the year 1805, a total of 14,577 tons of rope and other cordage were received into store, 6881 tons produced by the Royal Dockyards and 7696 tons from contractors. In this year - 1805 - which saw 62 dockings (Table 4.2) Portsmouth made only 1633 tons, less than either Chatham (1938 tons) or Plymouth (2120 tons)[42].

All canvas was bought as woven bolts of cloth which were twenty four inches wide and thirty eight yards long. Made with a warp of 560 double threads, it came in different weights depending on its use. No. 1 canvas[43] was the heaviest at forty four pounds to the bolt and was made from hemp whilst the lightest was No. 10 at fifteen pounds/bolt and was made from flax. Canvas was used to make sails, hammocks, screens, awnings, covers for boats and 'bolsters' which were used to prevent wood or rope chafing against each other.

5.8.2.3. Wood: - In the wood area the major bought-in items were pulley blocks although the Dockyards did make some themselves; principally the very big ones and of course the Yards inevitably undertook some repair work, where this made economic sense. Blocks consisted of an outer shell with a circular pulley or sheave which rotated round a pin or coak and deadeyes were blocks without a sheave which were used to secure the standing rigging.

Taylors[44] of Southampton had held the contract to supply blocks to the Dockyard since 1770 when all Portsmouth's reserve supply of blocks had been destroyed by fire. Subsequently, the contract of 8 April 1791 gave Taylors a monopoly with an annual turnover of 100,000 blocks although by 1806 the Navy's annual consumption of blocks had risen to 138,019[45]. Urged on by Bentham, the Admiralty was persuaded to invest in the development of the Navy's own blockmaking machinery at Portsmouth which first started work in 1803. However, as we have seen, 1803 to 1807 was a period of severe manpower problems in Portsmouth. At the same time, there was a shortage of certain raw materials such as lignum vitae for sheaves and delays to the production of iron pins and brass coaks by Portsmouth's own Metal Mills. The net result was that the mill did not achieve its full output until 1808 by which time it was producing 150,000 blocks of assorted types annually[46]. These mills, like the Metal Mills are discussed in more detail in later Chapters.

Other major bought-in wood items were treenails which were purchased in large quantities as well as being made in the Yard. To ensure a straight grain, treenails were split rather than being cut from oak and then rounded and finished by a treenail mooter - a moot being the special tool they used to round the wood. Treenails came in assorted sizes from half to two inches in diameter and twelve to thirty six inches long and their manufacture represented one use for waste wood in the Yard. Another use for waste wood was to make wedges which were used to force planks into place during ship construction.

5.8.2.4. Miscellaneous: - Under this heading, one of the largest purchases was ballast, either as shingle or more and more, as time progressed, in the form of iron bars. While shingle could be obtained from any suitable local source, iron ballast[47] was bought in bars weighing 56 lbs and measuring 12 ins by 4 ins by 4 ins, with holes cast into the metal to allow them to be moved and secured easily. Other items were provided as a matter of course by one of the Royal Yards to the others. For example, ships' ensigns and signal flags, which were made from a fine woollen material called bunting, were made exclusively in the Colours loft at Chatham.

5.8.3. Non Navy Board Stores: No ship was complete without the materials for conducting her own maintenance when away from port and these included mast sticks, canvas, rope and other items such as blocks. There were also the stores provided by the Ordnance Board such as shot, powder and small arms as well as the Master Gunners stores. Last but not least were food, drink and clothing provided by the Victualling Board for the maintenance of the ships company.

5.8.4. Infrastructure Items: In addition to those items needed for building or repairing ships, the Navy Board purchased all the materials for maintenance or improvement of the fabric of the Dockyard although Portsmouth Dockyard had its own Lime Kiln[48] for making mortar. As buildings were more and more being built in stone or brick, to minimise the fire risk within the Yard, greater quantities of stone, mainly from Portland, and bricks were needed. Wood was also needed for the internal fitting of buildings such as stores and offices and for the rafters and tiles for the roofs. Glass was bought for windows of buildings and for those in the quarter galleries on ships' sterns. From the 1790's, ships' sides and boats were painted and paint was needed for these as well as the yard buildings.

5.9. Dockyard Productivity - Overview. These few paragraphs bring together the salient features of the Output Analysis from Chapter Four, the Dockyard Workforce Analysis and the review of Material Inputs. As has already been shown in the comparison of the Output/Input analysis, there was an apparent increase in productivity of at least 14% across the period and this figure is almost certainly an understatement of the Dockyard's achievements. However, these were not achieved uniformly across the years between 1790 and 1815 which is best considered in three discrete sub-periods.

5.9.1. 1790 - 1800. "Years of Expediency": In these years output to the Fleet (Tons Sailing) dominated the management of the Royal Dockyards considerations. In Portsmouth even the medium, and certainly the longer term, considerations were subordinated to the short term imperative of despatching ships to sea for immediate operations. In these circumstances it would be churlish not applaud the decision to reduce the dry dock capacity between 1795 and 1803, in order to expand and enhance that capability for the future. Courageous it certainly was; far-sighted it probably was, particularly as the decision was taken at a time when the primary input of Dockyard personnel was proving particularly difficult to sustain let alone increase.

5.9.2. 1801 - 1807. "Years of Uncertainty and Confusion": Output to the Fleet fluctuated widely as peace followed war and war followed peace. As importantly, the manpower situation, which was already bad, deteriorated still more as the Admiralty stubbornly resisted demands for a long overdue review of the pay scales and pay arrangements for Royal Dockyard personnel. Fortunately the improvements to the dry dock facilities in Portsmouth, which are discussed in detail in Chapter Seven, had been completed by the start of this period and thus a primary constraint on increases in "Output" had largely been removed. Indeed the peaks in "output", as represented by Ton Dock Days, in 1803 and 1806 probably owe more to spare dry dock capacity and the ability of management to exploit it than it does to outright increases in productivity given that the manning levels in 1803 were the worst of the whole war period and they were not much better in 1806.

5.9.3. 1808 - 1813 onwards. "Years in Balance": By this time the management of the Royal Dockyards was beginning to benefit from a number of hard learnt lessons and the initiatives started in the earlier periods. In Portsmouth they had a good dry dock complex, the manpower problems had been brought under control and a range of technical innovations were coming on stream - the metal mills and blockmaking machinery; to mention but two of the new facilities, were beginning to prove their worth. Parallel investments in technology in other yards such as Chatham with its introduction of machinery into ropemaking, were also improving the Royal Dockyards' ability as a whole to meet the Fleet's requirements.

By 1813, Output, in terms of Ton Dock Days, at Portmouth had increased by around 107% whilst Input, in terms of the Dockyard workforce had only increased by a maximum of 93%. How much of the consequential 14% + efficiency improvement was due to the introduction of new technology and how much was due to administrative advances such as "out-sourcing" the manufacture of some products such as rope is an open question. Undoubtedly the lack of growth in the fibre workforce numbers at Portsmouth was due to a greater reliance on rope made in other yards or by sub contractors. Against this it must be remembered that Portsmouth's copper sheathing and block making facilities were serving the Dockyards as a whole and not just Portsmouth.

5.10. Overview of Portsmouth Dockyard Resources. It can be concluded that by 1808 the management of Portsmouth Dockyard as a whole had got the work of that yard well under control with changes in output and input being very closely correlated. As so often in the past, before the Napoleonic Wars and several times since that conflict, the management and infrastructure of the Royal Navy had been found wanting when war broke out but by the end of the fighting it had evolved into an impressive machine with a war winning capability based on evolution rather than revolution. Undoubtedly the Royal Dockyards' management had demonstrated a willingness and ability to invest in new technology but it had also shown that it was not going to be driven into a race for new technology for new technology's sake. The Input/Output analysis goes a long way to demonstrate that new technologies did indeed increase Portsmouth Dockyard productivity and thus were of real practical benefit.

1. B.R. Mitchell and Phyllis Deane, *Abstract of British Historical Statistics*, Cambridge University Press, 1962, pages 6 and 7.

2. Roger Morriss, *The Royal Dockyards during the Revolutionary and Napoleonic Wars*, Leicester University Press, 1983, Page 107. 5 George I, c.27 and 23 George I, c.13.

3. ADM 42/1127 to 1157 and 1306 to 1355. Portsmouth Dockyard Paybooks, Public Records Office. The first series are the paybooks for the Ordinary vote, giving the wages for the permanent staff of the Yard who were paid annually. These include salaries for Yard officers and their clerks, and crews of the ships in Ordinary and of the harbour craft. The second series are the paybooks on the Extra-Ordinary vote, giving daily pay rates for the workmen and details of workers paid on contracts. Details for the Midsummer Quarter only have been used.

4. Sixth report of the Commissioners of Naval Inquiry, *Naval Chronicle*, Joyce Gold, London, 1811, v.XV, p.56. Evidence of Richard Pering, Clerk of the Cheque at Plymouth, given 23 August 1803.

5. Morriss, op. cit. n.2, pp.100-105.

6. ADM 42/1316/2, Paybook for Midsummer Quarter, 1797.

7. ADM 42/1319/2, Paybook for Midsummer Quarter, 1799.

8. *Universal British Directory of Trade, Commerce and Maintenance*, 1798, v.4, and Pigot & Company's *National Commercial Directory*, 1823-1824.

9. James H. Thomas, *Portsmouth and the East India Company in the eighteenth century*, The Portsmouth Papers, No. 62, Portsmouth, 1993, pages 4 and 5.

10. A treenail mooter shaped the wooden fastenings for the ships hull with a specialist tool called a moot which gave the wood its rounded shape.

11. ADM 42/1313/3, signed by the Dockyard Commissioner, Sir Charles Saxton.

12. POR/D/30, Letter of 17 August 1814.

13. ADM/42/1306 - 1355, Paybooks for Midsummer Quarter, 1790-1813.

14. ADM 42/1313/3 Paybook for Midsummer Quarter 1795, page 132.

15. ADM/42/1127 - 1157, Pay for a Tapster for the smiths' beer appears in the paybooks for the Ordinary.

16. Abraham Rees, (ed), *Cyclopaedia*, Longmans, London, Volume IV, CAL to CAS, no pagination.

17. John McKay, *The 100 gun ship, Victory*, Conway Maritime Press, London, 1987, page 14.

18. ADM 42/1330, Paybook for Midsummer Quarter of 1800.

19. Jonathan Coad, 'Historic Architecture of HM Naval Base, Portsmouth', *The Mariner's Mirror*, (1981), 67, pp.20-22.

20. John E. Horsley, *Tools of the Maritime Trade*, David and Charles, Newton Abbot, 1978, page 172. Also in a display of shipwrights tools at the Maritime Museum at Bucklers Hard, Hants.

21. ADM 42/1306 to 1355, Paybooks for the Extra Ordinary, 1790-1813.

22. James Dodds and James Moore, *Building the Wooden Fighting Ship*, Hutchinson, London, 1984, page 45.

23. ADM 42/1306 to 1355, Paybooks for the Extra Ordinary, 1790-1813.

24. The origin of the word Scavel is obscure. The Oxford English Dictionary says it probably derives from an Old Norse word *skafa* to scrape or shave. References in the Dictionary are to marshes and drainage.

25. Dodds and Moore, op. cit. n.22, p.49.

26. ADM 42/1306 to 1355, Paybooks for the Extra Ordinary, 1790-1813.

27. ADM 106/3519, Memorandum dated 9 February 1808, Total number of blocks and deadeyes produced in 1806 was 154,285.

28. Morriss, op. cit. n.2, p.51.

29. 1702-13, War of Spanish Succession, 1740-48, War of Austrian Succession, 1756-63, Seven Years War, 1774-83, American War of Independence.

30. T.K.Derry and Trevor I. Williams, *A Short History of Technology*, Oxford University Press, Oxford, 1970, pages 486-488.

31. Joan Day and R.F.Tylecote, (eds) *The Industrial Revolution in Metals*, Institute of Metals, London, 1991, page 192, Copper, Brass and Zinc production, (Joan Day).

32. Bernard Pool, *Navy Board Contracts 1660-1832*, Longmans, London, 1966, page 88.

33. ADM 106/2230, Navy Board papers, page 705.

34. A.J.Holland, *Ships of British Oak*, David and Charles, Newton Abbott, 1971, pages 50-55.

35. Maurice Daumas - editor, *History of Invention and Technology*, Crown Publishers Inc. New York, Volume 3, pages 322-323.

36. Horsley, op. cit., n. 20, pp. 70-73.

37. Horsley, op. cit. n.20, pp.70-72 and Dodds & Moore, op. cit. n.22, p.14.

38. ADM 180/4 to 13, Progress Books, Description of wood used is included among the ships' details for those ships not built from oak.

39. Dodds and Moore, op. cit. n.22, p.23 and ADM 49/124, Account of foreign stores issued and expended, 1 January to 31 December 1774, Public Records Office, Kew.

40. ADM/180/4 to 13, Progress books and David Lyon, *The Sailing Navy List*, Conway Maritime Press, London, 1993.

41. Brian Lavery, *The Arming and Fitting of English Ships of War 1600-1815*, Conway Maritime Press, London, 1987, page 63.

42. Morriss, op. cit. n.2, p.87, extract from Table 19.

43. Rees, op. cit. n.16.

44. Gregory Clark, 'Naval Blockmaking in the Eighteenth and Nineteenth Centuries', *The Mariner's Mirror*, (1976), 62, pp.137-143.

45. ADM/106/3519, Memorandum dated 9 February 1808.

46. Morriss, op. cit. n.2, p.51.

47. P.W.King, 'Iron Ballast for the Georgian Navy and its Producers', *The Mariner's Mirror*, (1995), 81, pp.15-21.

48. ADM 140/555, Maps of Portsmouth Dockyard for the years 1790, 1793, 1796 and 1810.

CHAPTER SIX
AVAILABLE TECHNOLOGY WITH DOCKYARD POTENTIAL

6.1. Available Technology with Potential for Application in Portsmouth Dockyard. Chapter Six explores the advances and changes in technology that could potentially have been applied in Portsmouth Dockyard between 1790 and 1815. To do this it examines the history of technology in relation to the review of the Dockyard workforce; their craft and trade skills and associated tools and raw materials, contained in Chapter Five and the earlier chapters. It is often forgotten that "natural powered engines", sometimes quite sophisticated, existed for hundreds of years before man discovered how to "generate" steam power on a commercially viable scale. Certainly in the late 1700s Portsmouth Dockyard was totally reliant on muscle powered "lift and shift" engines for many of the activities it undertook and would continue to rely on them for many more years.

This Chapter starts therefore by examining those natural power sources used in dockyards and those "engines" common across all their activities/areas. It then moves on to consider the technical advances which were potentially available in each of the four "Resource" areas - Metal, Fibre, Wood and Miscellaneous - used in earlier Chapters. The consideration of the "miscellaneous" area in this chapter is principally focused on "structural" matters and "afloat" aspects. Each area ends with a table which attempts to illustrate, on one page, the relevant advances which were available and those which were exploited by Portsmouth Dockyard in that area. The selection of items for inclusion in these tables makes no attempt to be a comprehensive listing of all developments - rather, it represents the Author's attempt to assist the Reader in establishing an "Overview" of the area. Where a particular advance was not exploited in Portsmouth and where it is not discussed further in later Chapters, the rationale for that lack of exploitation is considered before moving on to the next "Resource" Area.

The application of specific advances in Portsmouth Dockyard between 1790 and 1815 is examined in more detail in Chapter Seven where each advance is examined in relation to the "Requirement" (Chapter Four), The Workforce (Chapter Five), the layout of the Dockyard itself and each other.

6.2. Power Sources, pre-1790's Origin: By the start of the sixteenth century, three natural power sources had become established. They were the muscles of humans and animals, wind and water. These supplied the day to day needs of industry and agriculture until the advent of steam power in the early eighteenth century. However this did not cause the immediate demise of earlier power sources, indeed all existed side by side for the eighteenth and most of the nineteenth centuries until steam was in its turn overtaken by other power sources, such as the internal combustion engine and electricity.

6.2.1. Human Power: The muscles of humans and animals have been used as a power source since the dawn of history but even with the aid of mechanical devices like the lever or the pulley, man could not produce large amounts of power, although he was versatile and flexible. In the context of Portsmouth's role as a repair yard man's greatest advantage as a power source was being able to move to the work site, however cramped or spacious that site might be. Whereas, when a large power plant like a windmill, waterwheel or steam engine was used, the work was taken to the power supply. It would not be until near the end of the nineteenth century that a suitable portable power supply would be developed that could be moved around easily for use in confined spaces.

6.2.2. Animal Power. Although several different types of animals had been used for a variety of tasks, by the late eighteenth century, the horse either singly or in teams was the most highly regarded in Britain. Horse power was limited by the number of horses which could be used simultaneously and many devices like horse gins were generally designed to be operated by one horse only, although some could be operated by teams of two, four or even six animals. In common with all forms of muscle power there were problems in operating animal power, since to maintain the power supply, tired horses needed to be replaced by fresh animals at regular intervals. There was also the cost of their maintenance and the periodic purchase of replacement animals. Like humans, horses were a flexible power source which could be deployed to the work in hand, whether it was moving carts and timber waggons or as the power supply for a fixed installation like a horse gin.

6.2.3. Wind power: Wind power operated through the medium of the windmill which had been widely used for centuries to grind corn or pump water but windmills can only operate when the wind is blowing, since there was no means of storing the wind energy for use later.

6.2.4. Water Power: By the late eighteenth century the waterwheel had become a significant source of power for industry. Water gave a steady even turning power and 'fuel' was readily available, cost nothing and in the event of a machine breakdown or a failure of the fuel supply, the system tended to come slowly to a halt without damage to any machinery which it was driving - what is today called 'graceful degradation'. However, to install a waterwheel needed considerable capital investment in the wheel itself and the associated structures such as a holding pond to maintain the head of water and leats to carry water to and from the wheel. There was also the building containing the machinery that the wheel would power and any gearing to connect one to the other. The real problem with water powered machines was of course that they had to be built where there was an adequate water supply such as a stream or river. Bentham did propose to use an overshot waterwheel to act as a power source for the Carpenters and Joiners shops at Plymouth in 1796, but the idea was not adopted[1].

A variant of the waterwheel was the tide mill. These were generally sited on sheltered tidal creeks and the wheel was driven by sea water which was stored in a holding pond at high tide. There were a number of tide mills in the neighbourhood of Portsmouth, for example at Fareham, Hayling Island and Emsworth, which has a mill pond of 10 acres[2]. Although a tide mill might well have supplied Portsmouth Dockyard with an adequate power source, there were disadvantages which would have made it an unlikely choice. A mill pond of 10 acres placed within the then existing dockyard limits of 82 acres[3] would have removed one eighth of the useable ground. Unlike a tidal creek site where it was comparatively simple to construct a holding pond, to build such a structure adjacent to the Dockyard would have needed extensive and expensive walling. Also a structure of any size encroaching onto the harbour would have affected the amount of silt deposited in it which was already a problem. In 1801, Samuel Bentham considered an apparatus to work a tide mill designed by a Mr Johnson. It was an interesting concept as it was designed to work on both an ebb and a flow tide not just the ebb tide generally used. Bentham felt that although the method was feasible, neither the Royal Dockyards not the Victualling Board had an immediate use for it[4].

Although the Dockyards did not have either wind or watermills, the Victualling Board did use them. The Weevil Yard at Gosport had a windmill as part of the brewing operations[5] and there was a cornmill driven by water in Portsmouth. Indeed from 1781, the main Victualling Yard at Deptford had a cornmill capable of grinding 400 quarters of grain per week, powered by a water wheel built by John Smeaton. The wheel had a diameter of thirty feet and was seven foot six inches wide. Smeaton sets out his reasons for using a water wheel rather than driving the mill machinery directly by steam in a letter to the Victualling Board Commissioners in November 1781[6].

In summary, both wind and water powered machines were dependent on the elements for their 'fuel' supply and if this ceased, they could not operate. Both needed considerable capital expenditure to set them up, and because of the size of the structures involved, - the tide mill at Woodbridge in Sussex had a waterwheel of 23 feet diameter and 6 foot 6 inches wide[7] - they were static power supplies more suitable for repetitive tasks such as grinding or pumping where the work could be brought to them. They were not sufficiently flexible or regular for many of the tasks within Portsmouth Dockyard, and would have taken up valuable space on a site which could not be endlessly expanded.

Table 6.1 summarises the general advantages and disadvantages of employing the various available power sources in and around a dockyard. From this it can be seen that the introduction of steam power was by no means a panacea for overcoming the disadvantages of the established power sources on such a site. Indeed, it can be said that the value of introducing steam was initially limited to use in the workshops (factories) and to those situations where the work could be brought to a statically positioned machine which could be operated for considerable periods at a time. The one obvious example of such a situation was that concerned with the pumping of fluids. However, "power" on its own was only half the problem and the other was the machinery to exploit it. As will be seen it was frequently the development of the machinery, which in turn depended on advances in both mechanical engineering and, as if not more importantly, on advances in metallurgy, rather than advances in the generation of steam power itself which was to be the deciding factor in dictating where and when this new source of power could be exploited.

TABLE 6.1 - APPLICABILITY OF POWER SOURCES FOR WORK WITHIN PORTSMOUTH DOCKYARD

BROAD NATURE OF WORK AND CRITERIA FOR IT	WORK WITHIN THE CONFINES OF A SHIP'S HULL/RIGGING TOOLS DEPLOYED TO ELEMENT BEING WORKED ON VARIABLE POSITIONAL RELATIONSHIP BETWEEN TOOL(S) AND ELEMENT BEING WORKED ON	WORK WITHIN A FACTORY TOOLS DEPLOYED TO ELEMENT BEING WORKED ON VARIABLE POSITIONAL RELATIONSHIP BETWEEN TOOL(S) AND ELEMENT BEING WORKED ON	WORK WITHIN A FACTORY ELEMENT BEING WORKED ON DEPLOYED TO TOOLS (& MACHINE) RESTRICTED POSITIONAL RELATIONSHIP BETWEEN TOOL(S) AND ELEMENT BEING WORKED ON	"LIFT & SHIFT" POWER SOURCE & MECHANICAL ADVANTAGE DEVICE(S) DEPLOYED TO ELEMENT TO BE MOVED	"LIFT & SHIFT" POWER SOURCE STATIC MECHANICAL ADVANTAGE DEVICE(S) EITHER WITH POWER SOURCE OR WITH ELEMENT TO BE MOVED
APPLICABILITY OF POWER SOURCES HUMAN	YES - THE ONLY OPTION	YES - THE ONLY OPTION	YES IN THE ABSENCE OF A HIGHER POWERED/LONGER DURATION POWER SOURCE	YES LIMITED POWER OUTPUT FROM AN INDIVIDUAL LIMITED DURATION OF POWER APPLICATION FROM AN INDIVIDUAL	YES LIMITED POWER OUTPUT FROM AN INDIVIDUAL LIMITED DURATION OF POWER APPLICATION FROM AN INDIVIDUAL
ANIMAL - HORSE	NO	NO	YES BETTER ALTERNATIVE THAN HUMAN BUT ONLY IN THE ABSENCE OF A HIGHER POWERED/LONGER DURATION POWER SOURCE	YES BETTER ALTERNATIVE THAN HUMAN.	YES BETTER ALTERNATIVE THAN HUMAN BUT ONLY IN THE ABSENCE OF A HIGHER POWERED/LONGER DURATION POWER SOURCE
WIND	NO	NO	NO - IN PORTSMOUTH LOW LYING, SHELTERED SITE GAVE LITTLE ASSURANCE OF SUFFICIENT WIND BEING AVAILABLE WHEN REQUIRED	NO	NO - IN PORTSMOUTH LOW LYING, SHELTERED SITE GAVE LITTLE ASSURANCE OF SUFFICIENT WIND BEING AVAILABLE WHEN REQUIRED
WATER	NO	NO	NO - IN PORTSMOUTH FLAT SITE DID NOT HAVE SPACE FOR SUITABLE RESEVOIRS AND SUFFICENT "HEAD"	NO	NO - IN PORTSMOUTH FLAT SITE DID NOT HAVE SPACE FOR SUITABLE RESEVOIRS AND SUFFICENT "HEAD"
STEAM	NO	NO	YES - AS/WHEN TECHNOLOGY DEVELOPED THE POWERED MACHINES/TOOLS	YES - AS/WHEN TECHNOLGY DEVELOPED THE PORTABLE POWERED MECHANICAL ADVANTAGE DEVICE(S) AND ASSOCIATED MOBILE STEAM ENGINES	YES

6.3. Lift and Shift Engines - pre-1790's: Of all the activities which occurred around a Dockyard, two were common to all work areas and they were "lift" and "shift". Therefore these are addressed now as a prelude to discussion of the use of steam and the application of new technology in the areas of metal, fibre, wood and miscellaneous work.

In the first century AD, Hero of Alexandria said that five simple machines could be used to move the world; they were the lever, wedge, screw, compound pulley and wheel with axle. Either on their own, or combined together in a machine, they were the basis of all machines many of which were built of wood with metal being used in small quantities either for specific parts which took a great deal of wear or for strengthening high stress joins in the woodwork. The wood used was frequently of any type which came to hand and the resultant machines were often of crude construction. In general, although, large and solid, they could be erected as and when required. Certainly they were less likely than later machines to be permanent structures; even where a combination of machines were sited together.

6.3.1. Levers: Leverage would have been used for many tasks in a Dockyard such as moving timber into piles for seasoning, stone for building or, with the addition of rollers, positioning large weights of any type. Furthermore, leverage could be applied to move a load either horizontally or vertically or in both planes simultaneously. At their smallest and simplest, they could be seen in devices like the crowbar and timber hooks and more sophisticated examples are shears for cutting metal or wheelbarrows.

6.3.2. Sheerlegs: A simple lifting device could be assembled by using a combination of single and double pulleys slung from the end of a yard on board a ship and operated by men pulling on the rope to raise the load. Sheerlegs were, and are, a machine using two long straight timbers lashed together at one end with the other ends braced and lashed at ground level so that they formed an A frame with the pulleys suspended from the apex. Alternatively a set of sheerlegs could take the form of a free standing triangle with a third leg added to give stability. The great attraction of sheerlegs was that they could be erected anywhere they were needed; on board ships, on the building slips, and around the dockyard.

As was mentioned in Section 4.2.4, the Royal Dockyards used old warships cut down and fitted with permanent sheerlegs for the purpose of removing old masts and putting in new ones. This use of hulks had the additional advantage that the large heavy mainmasts could be floated out to the hulk from the mast house where they were made, rather than trying to manoeuvre them around the Yard, although the East India Company, at their dock at Blackwall on the River Thames, had a specially built masting house[8] which included facilities for removing and fitting masts in ships.

6.3.3. Small Cranes: Commercial ports and docks used small cranes fixed to the gables of warehouses for lifting and lowering goods. It is reasonable to suppose that the eighteenth century Royal Dockyards had similar wooden structures because the storehouses were three stories high and without them items stored on the top floor would have had to be carried up and down manually. This would have used a considerable amount of manpower whereas fewer men could move the same amount with a small crane. This conjecture is supported by evidence from among a series of sketches made by Goodrich in October 1813, which shows a small crane for manual operation for the new Millwrights shop which was to be at first floor level above a coalyard[9].

For unloading on quays, the treadwheel crane, which was a fixed structure, was used and the earliest surviving example is the single wheel crane at Harwich[10]. Maps[11] of Portsmouth Dockyard show that among others, there were three treadwheel[12] cranes positioned on the Camber Quay for unloading stores from ships. Each crane had two human operated treadwheels with one on either side of the crane housing - this made a more stable structure than the one wheel arrangement.

6.3.4. Ground tackles: Sheerlegs and cranes both move loads vertically, whilst loads were moved horizontally along the quayside, or up a slipway or inclined plane with tackles, which were a system of pulleys and ropes attached to a fixed point. Tackles could control downwards as well as upward movement so they were used to lower heavy loads and put boats back into the water as well as get them out.

6.3.5. Windlasses: The windlass and the capstan are two machines which came in a range of sizes and were based on the wheel and axle which acted as force multipliers relative to the handles/bars on which the operators pushed. The principal difference between the two was that in a windlass the axle was horizontal and in the capstan it was vertical.

The windlass was a relatively simple device with its axle often being formed crudely from little more than a trimmed tree trunk. This was positioned between two uprights and was fitted with long handles at each end which were operated by a number of men. An alternative design had two sets of bars, set at ninety degrees to each other, at one side of the axle only. The windlasses fitted in ships were used for the general handling of ropes and in the dockyards their numerous applications included being used by the riggers to stretch rope under constant tension for a number of hours at a time.

6.3.6. Capstans: The capstan, unlike the windlass, was one of the most sophisticated of the lift and shift devices and certainly one of the most powerful[13]. It basically had three parts - a fixed toothed path and pawls at the bottom, the drum around which the rope was endlessly rove in the middle and the head at the top through which the power was applied. The pawls were small metal 'bars' which were fitted on hinges on the drum and engaged with a toothed path on the fixed structure. As the pawls were longer than the distance between their hinges and the teeth, they trailed over the latter at an angle of around 45 degrees when the drum turned in one direction. As soon as the drum tried to turn in the opposite direction, the pawls immediately dropped down into the gaps between the teeth and thus prevented any movement in that direction. This effectively stopped the load taking charge and spinning backwards if for any reason the power being applied was inadequate to sustain the movement in the required direction or if the capstan was being used to establish a particular tension on a rope or cable. To allow the capstan to run backwards, the pawls were rotated on their hinges through 180 degrees.

The drum, which was mounted on a spindle, was made in the form of a waisted cylinder so that the rope going round it, often three or more turns, always tended to ride into its centre. At the top of the capstan was the head into which four slots, or recesses, were built on a dockyard capstan and up to twelve slots on a First Rate's main capstan. Into these went the capstan bars on which the operators pushed with all their strength. On the bigger ships, a double capstan was fitted with drums and bars on two decks. Not only did this arrangement allow cables to be worked on both decks but it also doubled the manpower that could be applied. In Victory for example, 260 men, who could together exert a force of 10 tons, were used when weighing anchor. Such power was needed in the first place to haul the ship up to the anchor against wind and tide, both of which could exert great pressure on a ship of that size. Then, once the ship was directly over the anchor, it and its cable had to be weighed and the anchor alone was 3.75 tons[14] and to that had to be added, at any given moment, and depending on the depth of water, some 200 feet or more of sodden 24 inch circumference[15] hawser-laid rope cable.

Within the Dockyard capstans were used for warping (pulling) ships into their berths, into and out of dry dock and operating lock gates as well as moving caissons into position. Also numerous capstans were fitted strategically around building slips for moving and lifting timber frames into place. The capstan had the great advantage that since the rope was wound round it, rather than being fixed to it, there was no limit to how long the rope was and indeed, if required, successive ropes could be joined together, with suitable 'bends and hitches' which themselves could pass round the drum. As well as installed machines the Dockyard also used small moveable capstans called 'crabs' which had two long bars going right through the drumhead from side to side.

Apart from the power that capstans could generate, they were inherently extremely safe and sensitive under very heavy load conditions. Even if a capstan bar, or the actual capstan drum head itself broke or split, the pawls would stop the load taking charge and the weight on the rope could actually be eased by what was called 'surging' it round the drum. 'Surging' is releasing the pressure on the 'inhaul' end which reduced the friction between the rope and the drum and allowed the load to take charge, although it was always under control. It may be a statement of the obvious but nevertheless it is important to remember that the greater the pull being generated the more solid had to be the arrangements for ensuring that the machine itself did not move. Not surprisingly therefore the majority of capstans found around a dry dock, or a refitting berth, which were used from time to time to move ships themselves, were permanent installations and their lack of mobility was overcome by fitting them in significant numbers - typically four (or even more) around each dry dock.

Both capstans and windlasses have survived the test of time. The materials from which they are made changed from wood to metal and successively powered by man, steam, hydraulics and electricity, they still perform the same tasks in the same way. Interestingly, in Portsmouth Dockyard today, powered warping capstans are normally worked by running them at constant speed and changing the pull they exert on a ship by varying the tension that two or three men exert on the 'inhaul'.

6.3.7. Dockyard Lifting Craft: As well as those dockyard craft mentioned in Section 4.2.4 for moving men and stores around the harbours and anchorages, all the Royal Yards used a range of specialist lifting craft[16], and Portsmouth had a number of such boats. There were five chain boats which carried chains for the permanent moorings within the harbour and six mooring lighters which could lay or take up the moorings. These lighters were fitted with a simple derrick crane with a moveable boom fitted with pulleys and cables and a capstan for lifting heavy weights. There was a buoy boat which laid or took up the buoys used to mark navigable channels into harbour, and tank vessels which were fitted with iron tanks and pumps so they could supply water to ships at anchor. There were also dredgers but these are discussed later in this Chapter.

6.3.8. Pumps and Pumping: The machines discussed so far were only a practical means of moving water in any volume if it was contained in barrels; for large quantities, pumps were needed. This requirement was by no means unique to the seafarer since on land there were the ever growing needs to keep mines and agricultural land free of unwanted water and this was as important to their communities as keeping ships dry was to the maritime world. Not surprisingly therefore many improvements to naval pumps were suggested by landsmen.

Dockyards had an additional interest in both flooding and draining because of their use of dry docks. The earliest of these were built to discharge water, or flood, using the tides and natural drainage. However the size of vessel a dry dock could handle was dependent upon the height of the tide which only reached a peak, or trough, once a lunar month. In the interests of getting ships in and out of dry dock when required some form of simple pump was clearly needed to augment the tidal range. From the time of Dummer's dock-building programme in the 1690's pumping was used at Portsmouth and by the 1790's, there were three pumphouses in the Dockyard. The pumps were probably two sets of chain pumps for each pumphouse and were operated by a gin driven by a six horse team. These pumps could raise seven tons of water per minute[17].

6.3.8.1. Chain pumps had been developed by William Coles and Captain John Bentinck, Royal Navy and were brought into service in 1770[18] for use in ships where they were manually operated. The Chain pump had an endless chain running over a sprocket wheel and through two wooden tubes, one taking the chain down into the sump and the other returning it to the pump-head. The chain consisted of iron links and at regular intervals along the chain there were double iron discs with leather between them which was cut to fit the tubes. As the chain was turned and moved the discs through the up-tube, the water was trapped between them and raised to a cistern at the pumphead from which it was discharged. The chain pumps used by Portsmouth Dockyard (Figure 6.1) were made on exactly the same principles as ships' pumps, but they were much bigger - their iron discs had a diameter of twenty four inches - so more water was raised at a time[19]. In 1798, a 12hp engine replaced the horses used to drive the large Dockyard pumps and by 1800, plans for six chain pumps each capable of raising ten tons per minute were being considered with power to be supplied by a 30hp steam engine.

<u>6.4. Lift and Shift Engines - Candidates for Steam Power</u>. It can be assessed that relative to their suitability for the application of steam power, the key requirements, or characteristics, of lift and shift machines around a Dockyard fell into four broad groupings:

<u>6.4.1. Docks, Building Slips and Fitting Out Berths</u>: these were all large areas along and across which, at many varying points, a "lift" could be required. Whilst the frequency of lifts across the area as a whole might have been high the frequency at any one point was low. The net result was that lifting (and shifting) machines were employed in large numbers and most of the smaller ones were portable. It was not until the techniques of building mobile cranes, with long and high jibs and using flexible wire rope for their purchases were invented that a few powered cranes became a realistic alternative to the many purchases hung from scaffolding, sheer legs and the ubiquitous capstans.

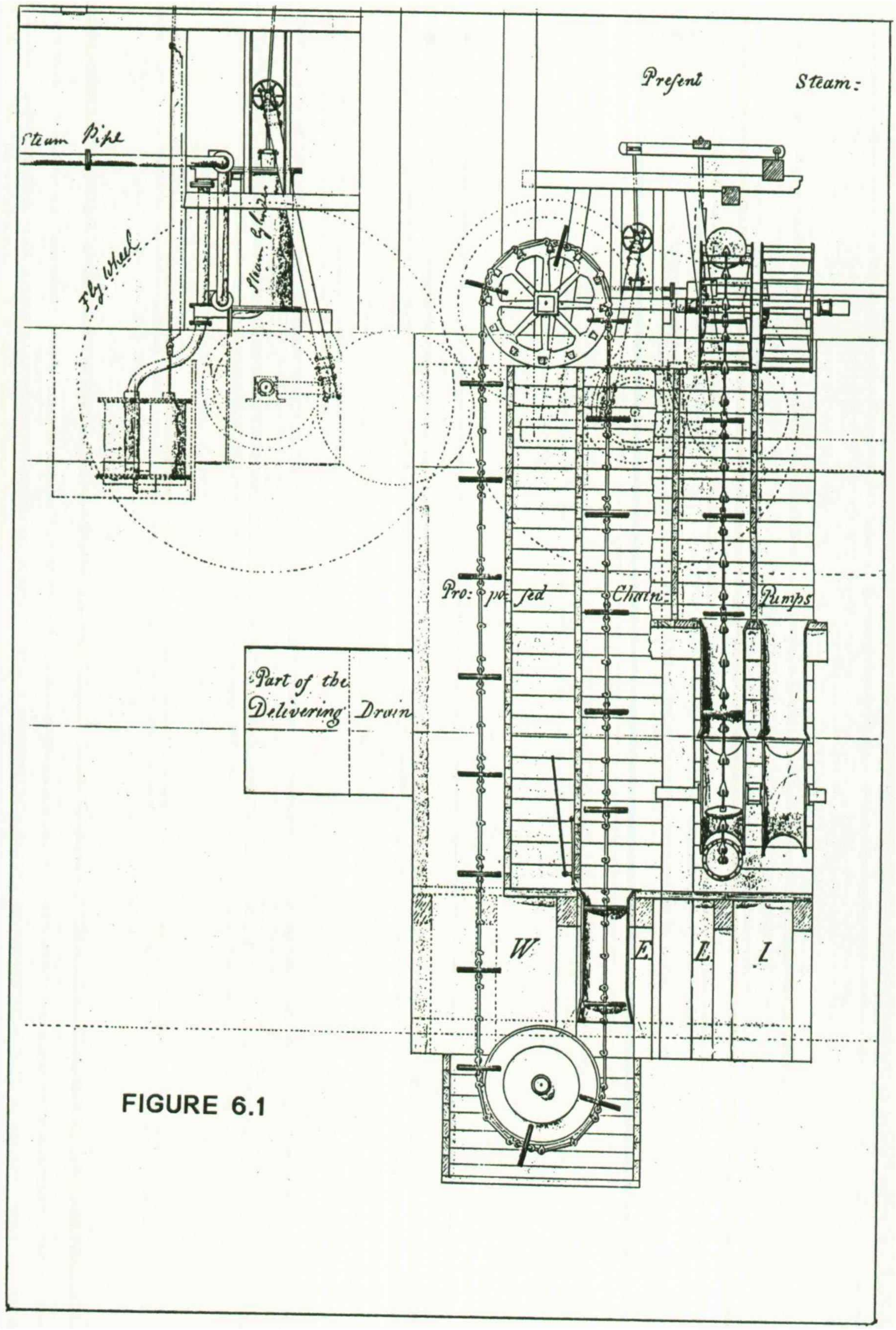

Present Steam:
Steam Pipe
Fly Wheel
Pro: posed Chain: Pumps
Part of the Delivering Drain
W E L L

FIGURE 6.1

6.4.2. Workshops in the workshops of this period only the Metal Mills were involved in the production of relatively heavy products like anchors and chains and the frequency of lifting raw materials in and finished goods out was very low compared to the length of the manufacturing process. Therefore the focus for investment was inevitably upon that process and it is difficult to envisage a case for introducing powered lifting devices which were not part of the production machinery.

6.4.3. Stores: within the dockyard there were two distinct stores types. Firstly there were the stores within buildings. Often on several floors where sensible design would have looked to multiple entrances and exits to reduce the length of travel within the building and hence the requirement would have been for several lifting points per store. Whilst unskilled labour was readily available, it is difficult to envisage an economic case being made for introducing multiple "powered" lifts when simple tread mill cranes were perfectly adequate. The other type of store were the external timber stowages which covered a considerable area. Again, mobility was the dominant requirement for the lifting devices quite apart from the fact that the frequency of lift at any one point must have been very low, so speed of re-location was as important as mobility itself.

6.4.4. Pumps: the fourth group is concerned with the pumping of water; both to empty or flood docks and for the distribution of water around the area of the dockyard as a whole and in particular for fire fighting which was an ever present requirement on a site with so much combustible material. In the case of the docks it does have to be remembered that there was still the need to bring the water to the pumps. Hence an integral part of bringing steam power to bear in this area was the rebuilding of the docks to introduce a sump or reservoir into which the docks could be emptied by gravity prior to the water being pumped out into the estuary.

6.4.5. Afloat Power: The requirement here which inevitably comes to mind first is propulsion and tugs but there were other areas such as dredging and afloat lifting devices such as mooring lighters. On the face of it these were all prime candidates for the application of steam power since, relative the structure they were fitted on, steam plants and their associated engines were static. Also the size of these vessels limited the degree of manpower that could be brought to bear and, because of the mobility inherent in the vessel, the plant was mobile. Portsmouth Dockyard exploited or planned to exploit steam power in all these cases prior to the end of the Napoleonic War and they are examined later in some detail in Chapter Seven.

In general terms (leaving aside the special case of "afloat" requirements) it can be deduced that in Portsmouth Dockyard, as far as solid objects were concerned, the predominant "lifting" (and shifting) requirements were for a few sporadic lifts in any one place but with a large number across the Yard as a whole being undertaken at any one time.

Furthermore lifting and shifting machines, driven by muscle power, could be 'stalled' without any adverse effect on the power source and power could be provided at the point where it was needed. Furthermore, it could be applied in any plane or combination of planes. Moreover if the power available was inadequate for the task in hand it could, within broad limits, be increased. It was to take the design of steam engines some time to evolve to the point where maximum torque could be applied to a static load and evenly maintained for a considerable period of time, with little or no movement of the load. Today, slipping clutches, safety valves and governors are taken for granted but all these had to undergo considerable development before steam power could be safely used in many of the 'safety critical' situations to be found in the process of lifting/moving heavy weights very accurately, often over very small distances. In the case of bulk fluids (primarily removing water from the dry docks) technology had already reached the point, by 1793, where it had much to offer the Dockyard.

6.5. Steam Power - Engine Developments. Steam was the major development in mechanical power sources during the eighteenth century and this process continued into the nineteenth century. By then other power sources were being discovered but it would be 50 to 100 years before most of them were in general use. They included gas, made from coke or coal and used for lighting and hydraulic power which is a means of transmitting energy through an incompressible liquid such as water. The hydraulic press, patented by Bramah in 1795 was the application of a small force to a piston with a small area which was moved over a long distance to create a large force on a large piston moving slowly over a short distance[20]. Since this was done very smoothly it was well suited to moving heavy objects, compressing and baling light bulky materials such as cotton, and testing the breaking strength of materials like rope. However the greater the mechanical advantage achieved, the slower the "power head" moved, and it would not be until much later that the fast-acting hydraulic servo systems we know today came into use.

The history of the development of steam power is well documented and Figure 6.1.1 shows vividly the size of engines of this period. These particular photographs are of the 31.5 hp engine at Crofton on the Kennet and Avon Canal. Built by Boulton and Watt in 1812, it is still in working order today.

6.5.1. Single Action, Lift Engines: The earliest steam powered machines were single-acting; that is to say they had a powered stroke followed by a return one. The number of applications for a steam engine of this type with a rocking motion - the reciprocating engine - were limited to operations which could accept a uni-directional power stroke such as pumping, blowing furnaces and hammering.

By the end of the seventeenth century as mines became deeper, there was an increasing need for a power source which could be used to raise water more effectively than the efforts of man or horse allowed. In 1698, Thomas Savery patented his work to produce a suitable power source based on an engine powered by steam[21]. Savery's steam engine was made possible by earlier work by Caus and Papin on the effects of steam pushing on a piston and von Guericke's work on the properties of a vacuum. By condensing steam in a receiver, Savery created a vacuum which could draw up water from below the engine and then use the steam pressure to force it up a pipe. Lifting and forcing pumps could only raise water a theoretical 32 feet (in practice significantly less), so a series of pumps were needed for deep mines.

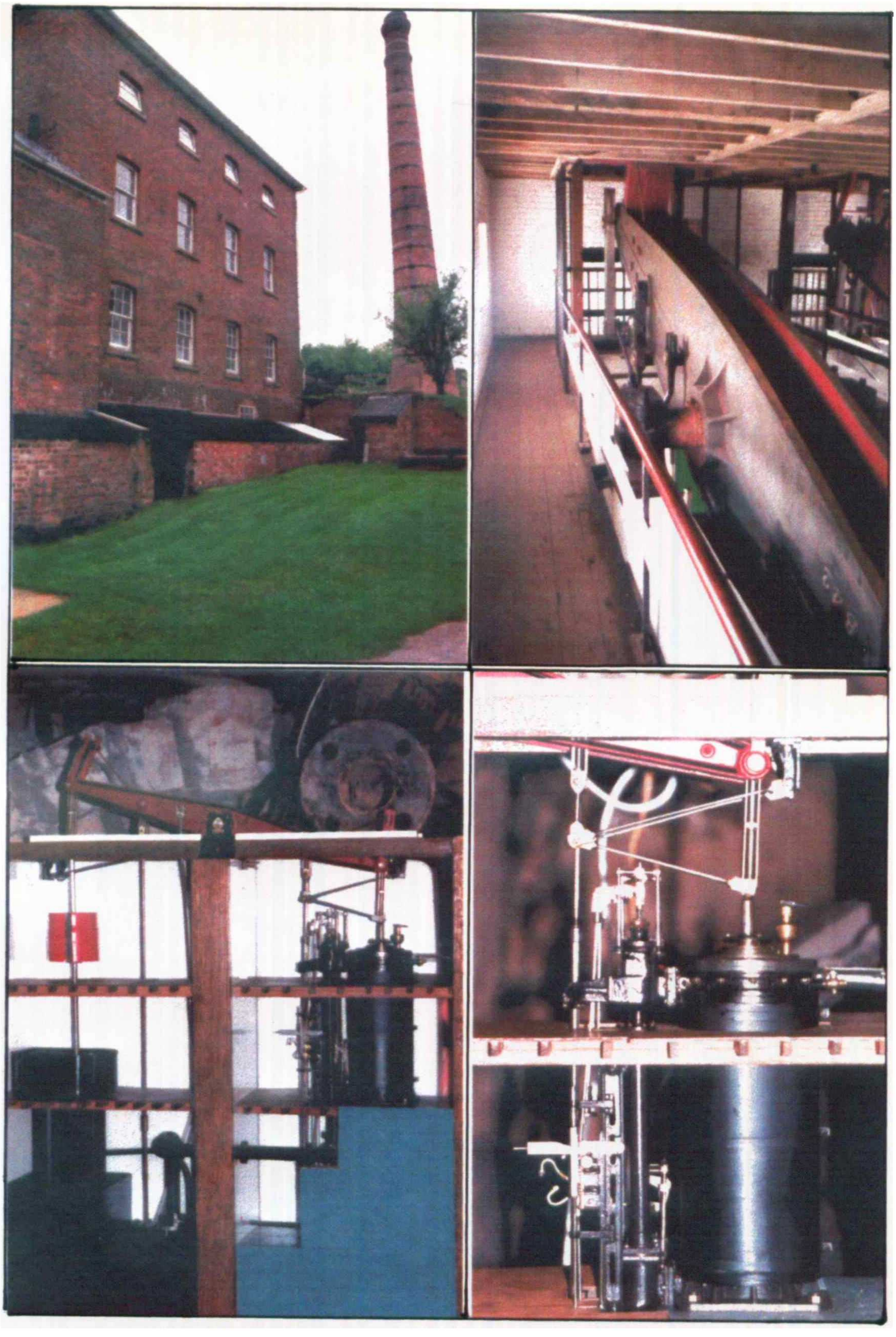


FIGURE 6.1.1 - CROFTON PUMPING ENGINE

A number of Savery engines were built and installed but the engine of Thomas Newcomen[22], which first appeared in 1712, was to have greater commercial success. In this a vertical cylinder, fitted with a piston, was positioned over a boiler which produced steam. The piston was attached by a chain to the curved end of a beam (arch-head), the beam pivoted around its centre and at the opposite end to the piston was a pump rod which was also attached to an arch-head by a chain. The pump rod went down the mine shaft. A jet of cold water condensed the steam in the cylinder thus allowing the piston to be pushed down by atmospheric pressure. At the same time, the pump rod rose at the opposite end of the beam, this in turn let water rise towards the surface. A pool of water on top of the piston stopped unwanted air leaking into the cylinder, and there was a valve to bleed off any which did get in. The supplies of steam and condensing water were regulated by the action of the engine - that is it say it was self-acting and as it used low pressure steam it was both safe and reliable and could be built with the limited engineering skills of the time.

Newcomen's engine was designed for pumping, the first being built at Dudley in the West Midlands. By the 1780's it was widely used on the Tyne coalfields and in the Cornish mining industry. As well as the capital costs of buying and erecting steam engines, owners also had to purchase fuel, normally coal, for them. Where Newcomen engines were erected on or close to coalfields, they ran on the small pieces of waste coal produced during the mining process. For the Newcomen engines erected in Cornwall, fuel had to be imported at considerable cost, so economies in the use of fuel were important. Subsequently many Newcomen engines were replaced by Boulton and Watt engines[23] as these gave a considerable saving in fuel.

Watt's patent of 1769 for a separate condenser[24] for the steam engine was the result of his work on a model Newcomen engine. In order to get a good vacuum and therefore power, the cylinder of the Newcomen engine had to be cooled down for part of the working cycle but to be economical, the cylinder should be kept hot at all times. Watt solved this paradox by the addition of a separate cylinder which was cooled to condense the steam, while the cylinder in which the piston worked remained hot. In order not to cool the cylinder further, by driving the piston down with air, steam was used instead. All Watt's engines used low-pressure steam as he felt that the likelihood of boiler explosions from steam at high-pressure would cause a loss of public confidence in the steam engine.

Watt's engine was manufactured in partnership with Matthew Boulton of Birmingham. Although the firm of Boulton and Watt were the premier engine builders of the late eighteenth century, there were other firms making steam engines for local rather than national markets, Fenton, Murray and Woods of Leeds, Phineas Crowther of Newcastle and Bateman and Sherratt.

The size of engine which the materials and engineering skills of the mid to late eighteenth century could produce, determined its power output, which in turn depended on the diameter of the cylinder and the length of stroke of the piston rod. If the pressure of the steam was increased the size of the engine, for the same power output, was reduced and therefore a high pressure steam engine was smaller than the equivalent low pressure one. There were also savings on fuel with high pressure engines and building costs were reduced as the space needed to install the engine was less. The use of steam at high-pressure was demonstrated by Trevithick[25], with his road vehicle of 1801, and the locomotive for the Pen-y-darren Ironworks in 1804. Subsequently his work on high-pressure steam engines was to form the basis of the development of the railway locomotive. A Trevithick engine was proposed for the second steam dredger to be used at Woolwich but was never fitted since a boiler explosion at Greenwich made the Admiralty decide to fit a table engine similar to that used in the Portsmouth dredger instead[26].

Another idea for using fuel to the best advantage was the compound engine which had two cylinders, one being a small diameter and the other a large. The steam first entered the small diameter cylinder where it dissipated some of its energy before passing into the large cylinder at a reduced pressure, but still sufficient to effect an energy transfer. This use of the steam allowed a better power output for the same amount of fuel. The first compound engines were made by Hornblower[27] and Son from 1781, but as they used relatively low pressure steam there was little advantage over a single cylinder engine. The idea was developed by Woolf[28] from 1804, using high pressure steam and it was this that led to the further successful developments of compound engines during the nineteenth century.

6.5.2. Double Action, Rotary Engines: Matthew Boulton had been one of the first to appreciate the potential of rotary motion from a steam engine and encouraged Watt to solve the problems of producing it. There were three problems which Watt had to overcome in producing rotary power from a steam engine. Firstly, the need to produce more power, solved by making the engine double acting. Secondly, so the piston rod could both push the piston down and pull it up, its linkage with the beam needed to be rigid. Thirdly, there was the problem of transmitting the power to a drive shaft.

Watt solved the problems with the three patents[29], that of 1782 for the Double Acting Principle, 1784 for the Parallel Motion and again in 1784 the Sun and Planet gear. The Double Acting Principle worked by closing the top of the cylinder so that steam could be injected on both sides of the piston rod and it could be driven up as well as down. This produced power throughout the cycle without an increase in the cylinder's volume and it also gave a more even motion. Any excess air and water was removed from the system by a small pump. For the piston to be able to both push and pull, the chain connection to the arch-head of the beam was replaced by a rigid connecting rod but this tended to induce loss of power and vibration as it moved away from the true line of the piston. To overcome this Watt devised his Parallel Motion which was constructed of wood with brass bearings and flexibly linked the beam to the piston rod so that the latter always moved in a straight line.

The final problem was how to connect the drive shaft to the machine and the most obvious way was to use a crank such as was already in use on the foot lathe and spinning wheel.[30] Unfortunately, this idea had been patented by Pickard in 1780, so Watt devised the Sun and Planet gear to perform the task. These were two toothed wheels, the Sun was on the drive shaft while the Planet wheel which was fixed to the connecting rod from the beam, moved around it. However, after the expiry of Pickard's patent in 1794 Boulton and Watt built engines with a crank rather than the Sun and Planet gear. A flywheel was used to even out the pull and push of the piston and give as smooth a power supply as possible to working machines. Transmission of power from the power source to working machines was done by line shafting and either gearing or belts.

It can thus be said that steam power became available for practical exploitation in the Dockyard work shops from around 1795 but of course that still left the necessary machinary to be invented and, as significant, the necessary building(s) to be erected. Figure 6.1.1. shows the size of the beam on the Crofton engine and flywheels of the engines of this time were approaching 30 feet in diameter. To widen the potential applicability of steam power it was obviously necessary to reduce the size of the plant and, ideally, make it re-deployable if not outright mobile.

6.5.3. Table Engines: In fact, during the late 1790's, efforts were being made to produce more compact engines, generally referred to as table engines. There was no beam, and the cylinder stood on a metal table with the piston rod being connected to the drive shaft mounted below the cylinder. Henry Maudslay patented such an engine in 1807, but Portsmouth Dockyard had installed a table engine designed by James Sadler in 1798, and by 1802, Fenton, Murray and Wood of Leeds were selling portable engines[31] of 1 to 6 horsepower. Undoubtedly there were other engines of this type around by this time although their records have failed to survive.

6.5.4. Transmission Arrangements: As machines became more powerful it became necessary to transmit power over several floors of a large building like a textile mill, so cast iron shafting and gears were introduced instead of wood. John Rennie[32] is credited with the first installation of cast iron shafting and gearing at the Albion Mill which opened in 1786. Gears and flywheels were cast in iron (Figure 6.2) and the inaccuracies in the working surfaces were removed by filing or grinding so as to avoid "chatter" and excessive vibration. Line shafting, also made from cast iron, was mounted above the machines and received its turning motion either by interconnecting gears or by a pulley and belt (Figure 6.2.1). Pulleys, which distributed the power to the machines, had a large flat rim on which wide belts made of leather were fitted. In some cases a rope take-off was used and in these circumstances the pulley rim was grooved to prevent the rope slipping off. Belts were arranged in an open loop between two shafts rotating in the same direction or crossed when the two shafts needed to operate in opposite directions. Both ropes and belts could be tensioned to prevent them slipping and conversely the tension could be released to allow machines to be disengaged from the system without stopping the prime mover.

FIGURE 6.2

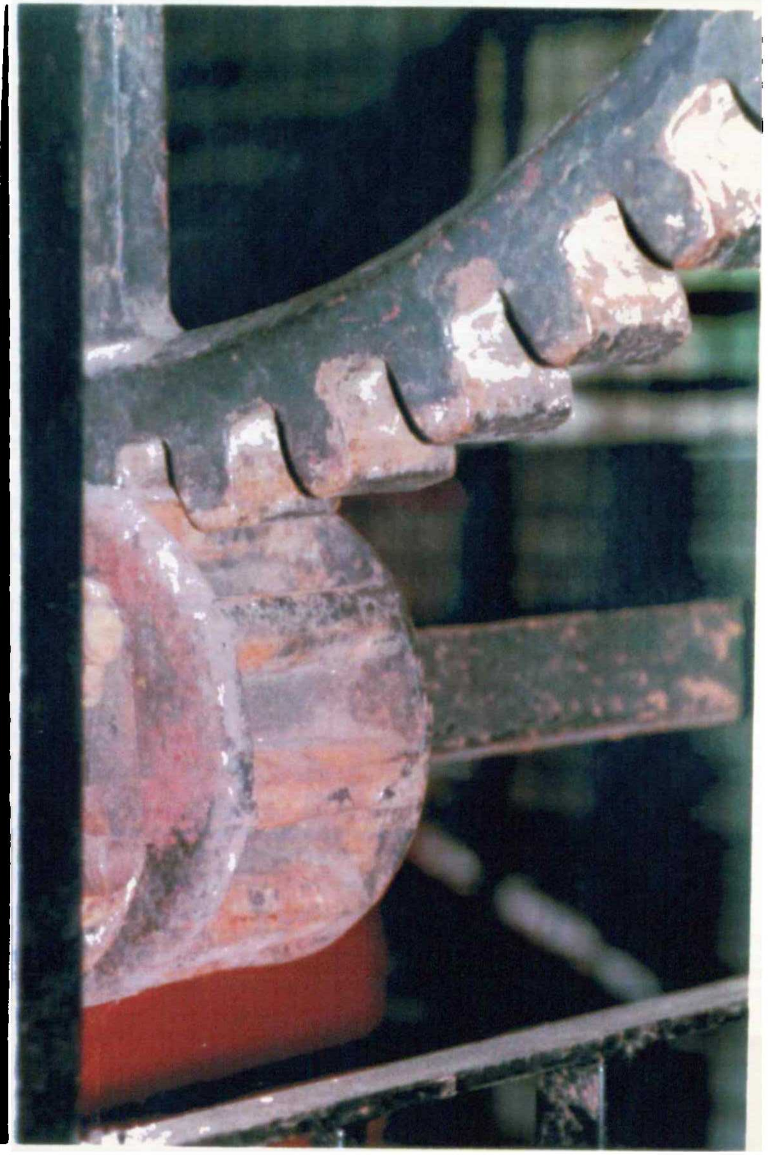


FIGURE 6.2.1

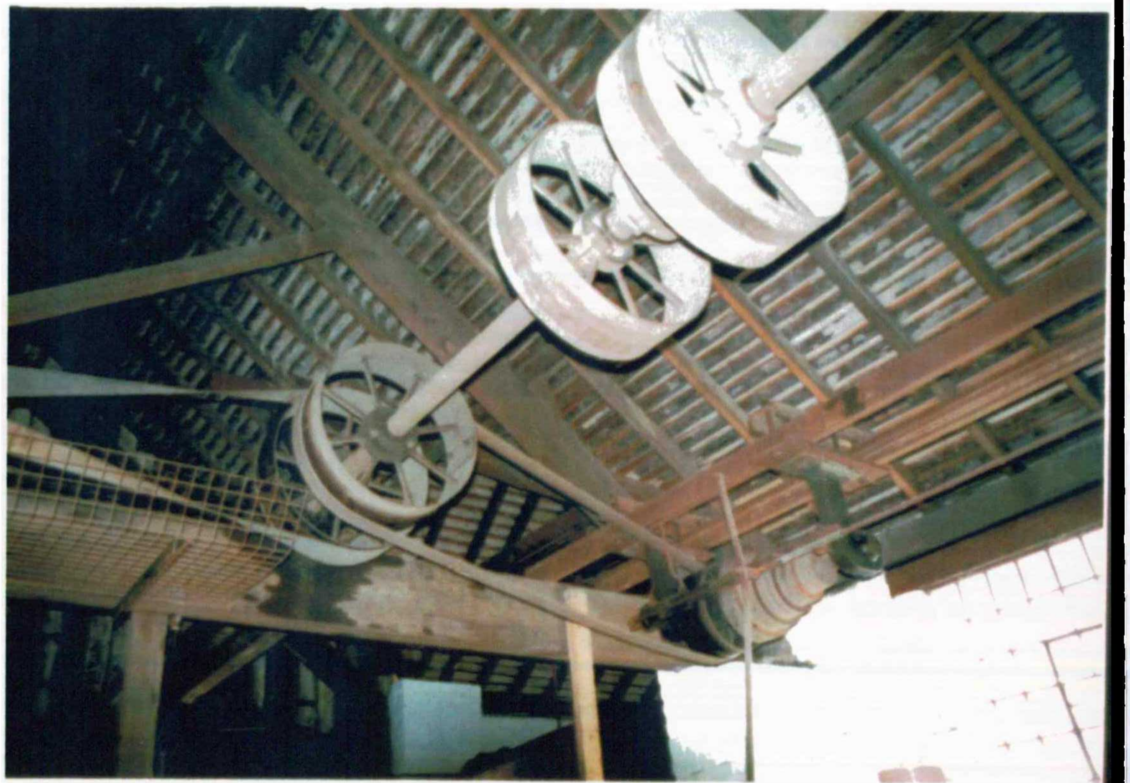


Table 6.1 has already outlined the key advantages and disadvantage of steam with respect to the older established sources of power. However there were a number of significant considerations which had to be borne in mind when assessing the value of introducing the new energy source.

6.5.5. Benefits of Steam Power - these included:

Potentially much greater power output was available from a steam engine than from muscles, wind or water.

Continuous operation was possible over sustained periods.

Steam powered plant was not dependent on variations in the weather or climatic conditions as was the case with wind and water.

With a static installation power could be distributed to a range of machines within that installation by gearing or line shafting.

6.5.6. Drawbacks with Steam Power - these included:

Work had to be moved to the steam powered machine(s) - powered machines could not yet be moved to the work wherever that was.

New skills were required of the workforce to operate the equipment, maintain it and repair it.

There were large "up front" capital costs involved in installing steam powered machines. There were subsequently the running fuel costs.

Machines had to be built to higher standards than had been demanded with wind and water power generators. This was particularly true of cylinders, pistons and seals, and these standards rose as the power demanded was increased.

Steam power was inherently inefficient and consumed fuel that had to be brought in.

Furthermore, for Portsmouth Dockyard, like any other Government Military organisation, there was the problem of how Parliament (advised by the Treasury) obtained and allocated funding. Unlike any commercial business no Government Department (other than the Treasury) was allowed to borrow money or acquire loans. Funding was allocated strictly on an annual basis and, as a consequence of the Civil War in the Seventeenth Century, such funding was required to be voted on and approved by the House of Commons - that situation continues to the present day. Hence Defence demands for capital investment in any one year were in direct competition with the demands of on going running costs[33]. Where capital investment was being sought as a basis for subsequent reductions in running costs the case made had to be sound and accepted by a range of sometimes "jaundiced" financial officials who all too frequently found that the promised savings failed to materialise.

With no avenue to the "city" and its investors the proposers of investment by the Government in new technology had to have both a sound case and real "presentational" flair. To a significant degree they had to be "lobbyists" and this was a skill which was not natural to the culture of a disciplined service like the Royal Navy. Nevertheless this skill was probably as important as the technical developments in achieving the introduction of what was expensive new steam powered equipment into Portsmouth Dockyard. Time and again the introduction of new technologies into the Navy Board's area of business were associated with just a few well known names such as Bentham, Maudslay and Brunel.

Against this background Table 6.2 suggests that Portsmouth Dockyard's record in exploiting the developments in Steam Power in the period 1793-1816 was impressive. Indeed the introduction of the James Sadler 12hp Table Engine in 1798[34] appears to be one of the very first recorded instances of this type of machine. What makes Portsmouth's record in this area even more impressive is the variety of uses to which the steam engines were put - these are reviewed in detail in Chapter Seven.

TABLE 6.2 - POWER DEVELOPMENTS

YEAR	DEVELOPMENTS PRE 1790	YEAR	DEVELOPMENTS 1790 - 1816>
1698	Savery's patent for a Steam Engine	1791	Rotative engines begin to replace atmospheric
1712	Newcomen's beam engine	1795	Hydraulic Press - Bramah
1759	Smeaton's work on water wheels	1795	First iron beam for a steam engine
1765	Boulton's trials with Savery engines	1798	Production of Gas from coke - William Murdoch
1769	Watt's patent for steam engine with separate condenser	1798	**Table engine 12hp - James Sadler**
1775	Boulton & Watt partnership begins 1 June 1775	1799	**Steam engine, 30hp Boulton and Watt - PORTSMOUTH DKD**
1775	Boulton & Watt patents extended for 25 years	1800	Boulton and Watt's patents expire
1776	Watt's steam engine in commercial use	1800	High pressure steam used by Trevithick and Evans (USA)
1780	Pickard's patent for crank	1801	**Moveable steam engine, Bentham/Sadler - PORTSMOUTH DKYD**
1781	Two cylinder compound engine, Hornblower	1802	**Steam engine of 54hp for the Metal Mills - PORTSMOUTH DKYD**
1781	Patent for rotative engine 25 October 1781	1803	Steam gauge & safety plug for loco boilers - Trevithick
1782	Patent for double acting principle	1804	Two cylinder compound engine, Woolf
1782	Rotative engine powering Wilkinson's Ironworks forge	1805	**Steam engine, 2nd 30hp,from Fenton Murray and Wood P.DKYD**
1784	Patents for parallel motion & sun and planet gear - Watt	1807	Table engine - Maudslay
		1821	Discovery of Electromagnetic rotation - Faraday

Note: Bold & Underlined = Application in Portsmouth Dockyard

6.6. Metals: Since the earliest years of this millennium, Man has manufactured a range of metal products for use in warfare. Today, museums and historic houses contain many examples of fine steel weapons and cast iron guns dating back to Elizabethan times. In the most general terms it could be said that the supply of the raw material kept pace with the demand for manufactured metal articles up to the middle of the eighteenth century. However, the situation changed with the trading opportunities opened up simultaneously by the successive wars and the Industrial Revolution. Together these factors generated a much increased demand for metals and an expanding range of metal products.

Portsmouth Dockyard felt the full force of these pressures since, by 1810, the size of the wooden fleet had virtually doubled with a corresponding increase in the demand for traditional metal products. In the same timescale advances in metallurgy and the demands of modern warfare saw the development of new products, like chain anchor cables, which were markedly superior in many instances to the non metallic products they replaced. Initially chain cables were used for permanent moorings in the Dockyards but subsequently, from around 1815, they were supplied to ships of the fleet[35]. The combined result was a major increase, across the period, in the requirement for metal output well above the 107% figure for the period suggested in Chapter 4 and this at a time when keeping the demand for raw materials under control was a matter of priority since most of the iron used by the Dockyards was traditionally imported from Scandinavia.

To enhance the productivity within Portsmouth Dockyard, whose smithy had been rebuilt in the 1790s, major new facilities were added. Starting in 1802 with the Metal Mills and later a Millwrights Shop which was followed by a new Iron and Brass Foundry. At the same time, all the main Royal Dockyards had alterations and improvements to their Smiths Shops. Work at Plymouth was undertaken in the late 1790s and started at Chatham in 1806 and at Woolwich in 1810 but it was Portsmouth that led the way in this area.

As ironmasters were able to produce greater quantities of both wrought and cast iron, it was used for a great range of things. By 1800, machines for the textile and other industries were being made of iron rather than wood so that they could withstand the vibration and constant use arising from the application of water or steam power to them. As more machines were made of metal, that was in turn used to strengthen the buildings which housed them cutting down the fire risk and allowing the upper floors of multi-storied buildings to sustain the weight of numerous machines with their gearing and lineshafting. This enabled a number of processes to be brought together, with centralised power source(s), on one site. Iron was also used to construct the water wheels, steam engines, flywheels and shafting which were used to drive industrial machinery, and for the machine tools like lathes which were used to make machinery for manufacturing where the metal was able to give greater accuracy as well as greater strength. From the 1830s the railways, which had been preceded by tram and plateways, also made increasingly large demands on the supply of iron products. Lastly, it must not be forgotten that the war itself generated a major increase in the demands for iron armaments - notably cannon, guns and shot.

The production of steel was still a relatively small industry geared to the production of cutlery, other cutting tools like shears and saws and of course small arms both for the military and the domestic markets. Huntsman's crucible process, developed between 1745 and 1750, had improved the quality of the steel, but it would not be made in large quantities until the 1850s.

Until the 1770s, the greatest use for copper was in combination with zinc to make brass. Brass was a staple material in the Birmingham metal trades which made a large range of items from cooking utensils and plumbers' wares to jewellery. However in 1776, during the American War of Independence, another demand for copper arose when the Admiralty introduced copper sheathing for the hulls of warships. By the French Wars from 1793 to 1815, many merchant ships were coppered as well. As the numbers of ships in both the Royal Navy and the merchant fleet rose, so did the demand for copper.

Ores of all these metals were found in quantity within Britain and in forms which could be refined with existing knowledge but it was the advances and innovations in smelting and refining which made the greater production levels possible. Discussion of the acquisition of resources for the Royal Navy in Chapter 5 highlighted the problems of timber and the demands on the available resources by house building and the expanding metal industries where it was used as charcoal in the smelting processes, in particular iron ore. A number of attempts were made during the eighteenth century to substitute coal for charcoal in the smelting processes. Although Abraham Darby had succeeded in using coke[36] instead of charcoal in his blast furnaces about 1712, it was not until after the middle of the century that the process began to gain acceptance by ironmasters. The pig iron produced was used in a molten state and cast into quite elaborate moulds but as it was brittle when hammered, it needed further heating with charcoal in a finery forge to make it malleable. Wrought iron which could be hammered into shape, was made with charcoal and contained far less carbon than cast iron therefore it had different properties and different uses.

One technique which used coal to refine pig iron was the 'stamping and potting' process patented by the Low Brothers in 1761 and 1763. The pig iron was broken up and put into clay pots with a lime flux and heated in a reverberatory furnace of the type which had been used in the production of copper, lead and tin since the start of the eighteenth century. Unlike in a finery forge where the metal and fuel were mixed together, in a reverberatory furnace the coal is heated in a separate chamber. The sulphur content of the coal cannot contaminate the iron and hot gases oxidise the impurities like carbon and silicon as they are drawn across the metal. When the carbon had been oxidised, the iron could be consolidated by hammering. This process was widely used by ironmasters but it was Henry Cort's patents of 1783 and 1784 that offered an alternative method of using coal in the refining of pig iron and a means of greatly increasing output.

Successive paragraphs discuss the nature of developments in forges, smithies, mills, castings, machining and scrap reduction with the detail of individual installations in Portsmouth being left to the next Chapter.

<u>6.6.1. Forges</u>: Portsmouth Dockyard was very much in the forefront of applying the new developments in the processing of iron and indeed can claim to have been instrumental in at least two of the significant developments of the period. Henry Cort's two patents came out of his approach to the Navy Board with an offer to reprocess old wrought iron mast hoops. Although Cort was actually a Naval Agent, he had married the niece of Mr Attwick who ran the Fontley Forge and had a contract to supply mooring chains and other iron objects to the Dockyards. Attwick handed control of the forge to Mr Morgan who in turn

passed it to Cort. After an initial contract with the Navy Board in 1780, Cort enlarged the forge and went into partnership with Samuel Jellicoe who provided additional capital.

By the early 1780's Cort was receiving quantities of old wrought iron from the Dockyards but he could not produce new items fast enough and therefore he stood to make a substantial loss. His experiments to surmount this problem involved the use of reverberatory furnace with coal fuel to heat the iron which was then put under a hammer. It was reheated to white heat and passed through grooved rolls to produce flat bars, rounds or squares. The bars were then cut and made into mooring chains, mast hoops or barrel hoops. Not only did the rolls produce good tough iron, but the process was much quicker and therefore cheaper than producing the same quality iron by hammering - rolling could produce 15 tons of iron in an hour compared with 1 ton by hammering[37]. The problems of having sufficient metal to keep the rolls working were solved by having several furnaces to one pair of rolls just as in the cotton industry the produce of a number of spinners supplied one loom.

6.6.2. Henry Cort: Cort was asked by the Navy if he could reuse old ships ballast which was made of cast, not wrought iron, and this led to his second patent of 1784[38] for the puddling process which amounted to a further development of a reverberatory furnace and a rolling plant. During 1785 and 1786, Cort conducted tests in all the Royal Yards[39] on iron made by this process and compared his product to the Swedish iron generally used[40]. The Dockyard smiths reported favourably on the quality of Cort's iron compared to the Swedish that they were accustomed to and Cort published a report on these tests which was seen, and taken up by Richard Crawshay of the Cyfarthfa iron works[41] - one of the biggest in South Wales, and this was a turning point in Cort's efforts to get his process for puddling accepted by iron masters.

Although there has been much debate on the validity or otherwise of Cort's patents of 1783 and 1784 (H.W.Dickinson[42], W.R.Morton and N.Mutton[43], R.A.Mott[44] and during the nineteenth century by Samuel Smiles and J. Percy in the 1860s) no-one appears to have queried if Cort would either have produced his dry puddling process or have had it accepted by iron masters without the interest shown by the Royal Navy. Or indeed, if the tests carried out in the Dockyards had shown the dry puddled iron to have been of an inferior quality to Swedish iron. Certainly the Fontley forge continued to receive contracts from Portsmouth Dockyard into the 1790's. In 1796, Portsmouth suggested to the Navy Board that some of their spare stock of iron should be sent to Jellicoe at Fontley to be made into mooring chains and swivels[45]. This idea was accepted, as was shown in two subsequent letters in which the Dockyard officers gave their opinion on the prices Jellicoe had asked for his work. These were £14 per ton for mooring chain and shackles[46] and £25 per ton for mooring swivels[47] which they considered reasonable having taken the prevailing level of wages into account.

The Navy Board's decision to issue contracts to Cort and Jellicoe for recycling their scrap iron was a pragmatic one to get the best value out of old stores; in hindsight it shows that even in the 1780s the work and provision of resources to the Royal Dockyards has a more influential place in the history of technology than is commonly supposed. Doubly so, as the money advanced to Cort for enlarging the forge by his partner's father was later found to have been embezzled from the Navy Board funds.

<u>6.6.3. Smithies</u>: As well as changes in the methods of smelting and refining metals, there were advances in the apparatus used. As blast furnaces became larger and took a greater charge of ore and coke, the air blast had to be stronger and bellows had to be larger and more robust. A typical blacksmith's bellows used to provide a blast of air for a forge consisted of three wooden boards joined together with a concertina of leather. However, this became worn with working and tended to split thus requiring it to be replaced regularly. Inside the bellows was a valve which opened and closed as the bellows were pumped up and down and expelled air through a nozzle set just above the level of the hearth. Blast furnaces and large metalworking establishments used bellows with cast iron boards which were powered by a water wheel but during the eighteenth century patents[48] were taken out for blowing cylinders which could be driven by a steam engine. These machines consisted of a cylinder with a piston which was operated by a reciprocating engine, and this expelled the air from the base of the cylinder down a blast pipe into the forge hearth. Wilkinson produced a steam powered blowing cylinder as early as 1776. A blowing engine was included in the equipment purchased for the new Metal Mills[49] at Portsmouth in 1803, although the Smiths continued to use bellows in their forges.

All metals could be worked manually, but this was very strenuous and time consuming work, even when undertaken by a team of smiths each striking the metal in turn before it cooled too much to become unworkable. From the fifteenth century, large forges had mechanical hammers which were driven by a waterwheel and later by a steam engine - Wilkinson had assembled such a plant in 1782. The earliest mechanical hammers; called tilt hammers, date back to the fifteenth century and were robust and straight forward being based on the lever principle. A tilt hammer had its shaft pivoted halfway between the head (hammer) and the tail, the head was heavier than the tail which was thus elevated in the static position. In use, the tail was depressed by a projection or 'cam' on a cylindrical barrel which was driven by the power source. As the cam moved round and out of the way it released the tail of the hammer and the head fell onto the anvil positioned beneath it.

By the end of the eighteenth century, there were two more types of hammer which had much heavier heads and delivered a slower more powerful blow than those of the tilt hammer. Both hammers had their pivot at the end of the shaft, but one, the belly helve was worked by the cams lifting a projection on the side of the shaft which raised the head and the other was called a nose helve, where the cam barrel was directly in front of the hammer. Again the cam raised the head of the hammer during operation. Of the three types of hammer the nose helve was the commonest type used for 'shingling' or working the iron as it came from the puddling furnace. The smithy built at Woolwich between 1810 and 1815 was fitted with steam powered hammers for making anchors[50] but the greatest problem with all these mechanical hammers was that of controlling the strength of the blow delivered. In the case of Iron, the blow needed to be softer for metal straight from the furnace and harder as it cooled. This problem was eventually solved when Nasmyth's steam hammer came into use in 1832.

6.6.4. Metal Mills: After the initial hammering, metals could be shaped into flat thin plates or bars by passing them through power-driven rolls[51]. The idea of rolls goes back to the sixteenth century and was introduced to overcome the difficulty of reducing metal into rod for nailmakers before it cooled so much that it could no longer be worked by hammering. To reduce bar iron to rod, a slitting mill was used but there were also plain rolls for producing sheets of metal or grooved rolls which were used to shaped bars into specific shapes such as rounds or squares.

Pairs of rolls made of cast iron were mounted one above the other in a stout cast iron frame (Figure 6.3). The rolls were rotated in opposite directions which forced a lump of metal presented to them through the gap between the rolls and as it came out the other side the metal became thinner and longer. The metal was returned to the starting point over the top of the rolls in what was known as a dead pass[52] - ready for subsequent passes through the rolls. The gap between the rolls was adjusted between each pass by the use of screws on the corners of the frame[53] and the rolls for producing bar iron, which were in diminishing order of size across the roll, had grooves to give the required shape to the material. The metal was passed through a series of these grooves until the requisite size was reached[54].

The slitting mill[55] was mounted in exactly the same way as rolling mills, but they were not as wide as the plain or grooved rolls. The slitting rolls consisted of discs with a steel rim mounted on an axle, with a spacer of smaller diameter between each disc. As the rim of the disc cut into the iron bar guides forced the cut metal either up or down over the spacer discs and thus split the iron bar into narrower strips. The width of the spacer discs controlled the final width of the metal rod produced.

One method of getting the rolls to contra-rotate was by connecting them to two separate undershot water wheels turned by water flowing in opposite directions and it was by this means that Henry Cort drove the rolling mill at his Fontley forge[56]. Different types of rolls were arranged on the same shafts so they were all driven by the same power source[57] but as it was difficult to adjust the two waterwheels to prevent one roll moving faster than the other, a flywheel was needed which was of a size to rotate three times to the waterwheels' once[58]. By the beginning of the nineteenth century rolling mills were also being powered by steam engines and again Wilkinson was early in the field taking out a patent for such a machine in 1792.

Although descriptions of rolling and slitting mills frequently refer to the iron industry, they could be used for any type of metal. Indeed it was for the re-working of Copper that the Royal Navy purchased rolling mills for use in Portsmouth Dockyard[59].

6.6.5. Casting: As well as forging metals, the Dockyard had Foundries for casting metals. All the metals commonly in use in the Royal Yards, Iron, Copper, Lead and Brass could be cast as well as forged. A mould of the required shape was made in a sand bed for very large objects, or in a mould box, and Abraham Darby introduced the idea of two part mould boxes in his patent of 1707[60]. The pattern was impressed into sand in the two halves of the box and when the halves had been put together the molten metal was brought from the furnace in a ladle and run into the moulds through a hole in the top (Figure 6.3.1). The mould was then left until the metal was cold and had set[61]. In an exchange of letters between the Navy Board and Portsmouth Dockyard officers in 1813, the Master of the Millwrights, William Kingston[62] suggested to the Navy Board that it would be possible to make an anchor with a hollow shank which could be cast from best-quality mixed metal[63]. The response[64] by Hamlet Vernon, Master of the Metal Mills to a query as to what would be required to make an anchor with a hollow shank gives some idea of both the equipment of a Foundry and the problems involved. Vernon said he would require a suitable space in which to do the work with room to move the moulds around within it, a large drying stove for the moulds, obviously of some more permanent material than sand, and a crane to lift them with a furnace to melt the metal. None of these were then available to him.

FIGURE 6.3

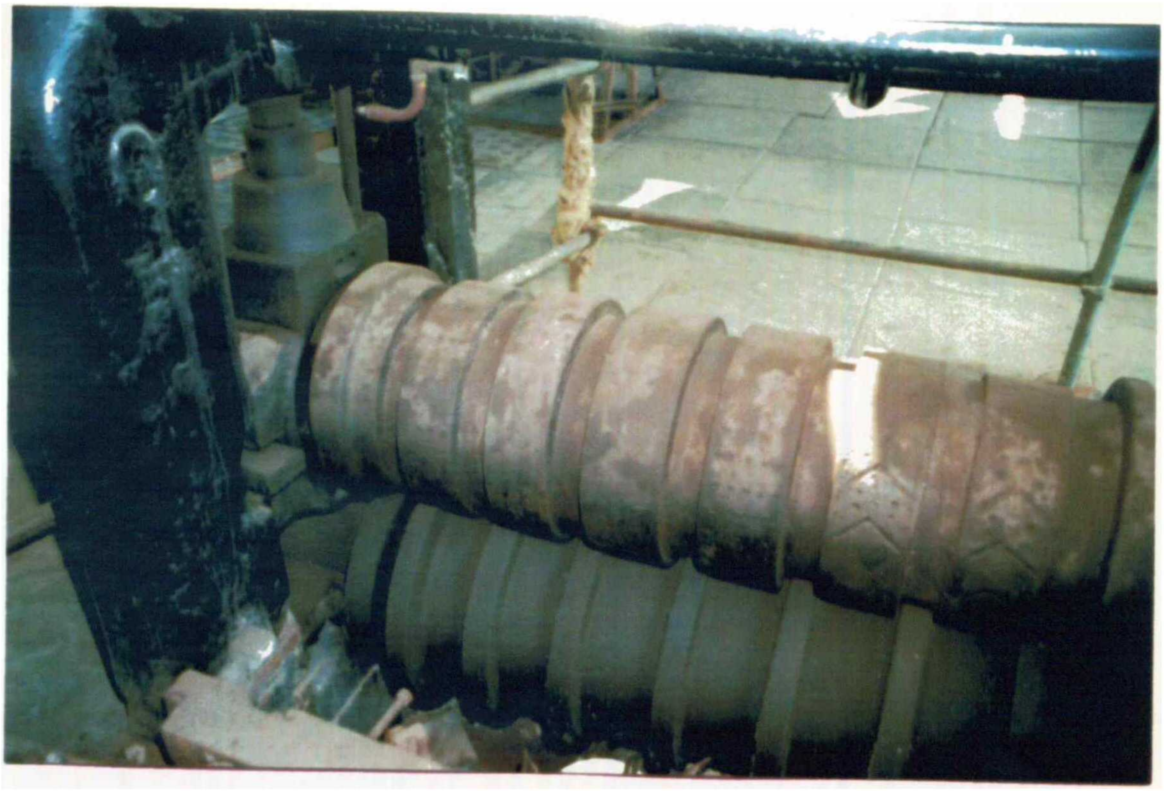


FIGURE 6.3.1

6.6.6. Machining: The advances in power, forges and mills led inevitably to greater precision in manufacturing metal goods but for their finishing, powered milling and grinding tools did not come into general use until towards the middle of the nineteenth century. For the period under review, "finishing" continued to be undertaken by traditional hand powered methods using files, grinding wheels or sand and rags. However machines for the intermediate operations between casting and finishing appeared earlier.

Hand shears were used to cut either sheet or bar metal and a punching and shearing machine, operated by three men, was installed in Portsmouth's Metal Mills in 1805[65]. In the second decade of the nineteenth century planes for metalwork began to appear and indeed Matthew Murray's plane was in use for the manufacture of slide valves for steam engines[66] as early as 1814. This was closely followed by a planing machine built by Richard Roberts[67] who is better known for inventing the self-acting mule for the Cotton Industry. However, 1818 saw the invention of one of the first examples of a milling machine by the American Eli Whitney[68]

6.6.7. Scrap reprocessing: Both copper and lead scrap could be reused after treatment in a melting furnace. New scrap, which was from shavings, and pieces which occurred during the shaping of the metal, could be melted and either rolled or cast into useable sizes. Old copper scrap such as the sheathing removed from ships' hulls would have been put into a melting furnace and when molten, the slag was skimmed off. Charcoal was stirred into the molten metal with a green wood pole which assisted the oxidation of any remaining impurities[69]. This was then hammered or rolled to produce sheets or bars of purified copper.

Quite obviously, as discussed at the start of this Section, the Navy and its Dockyards were forced by the Fleet's rising demands to invest in those technologies which enhanced their metal production output. However Portsmouth Dockyard's involvement in metal re-processing derived from other pressures.

Prior to the Portsmouth's facility coming into use, most of the Royal Dockyards were returning their old copper sheeting to commercial manufacturers by the long sea route around Land's End and up the Irish Sea - an area notorious for bad weather in winter and a graveyard for many small ships down the ages. Whilst the Channel routes to Portsmouth were not without some risk, they were firstly very much shorter and secondly along them were places to which ships could readily run for shelter. The net result of establishing a re-cycling facility at Portsmouth must have been a major saving for all Yards in transportation costs as well as the Navy having much less material tied up in "the pipe line". However the major reason for the change from "contracting out", as was the case with the old iron scrap sent to Cort's Fontley forge, to the building of extensive "in-house" facilities was in fact the search for quality. The lack of this was a constant problem with contractual supply and indeed Cort did not get his contracts until the quality of his product had been extensively examined. In the case of copper sheathing the Navy Board had received numerous complaints about the poor quality of contract processed copper and it could be said that their reversion to "in-house" facilities was actually in accordance with their established policy of building their ships, whenever possible, in the Royal Yards on the grounds that they had much more control over the quality of the materials used and the standards of workmanship applied.

In summary it can be said that during the late eighteenth and early nineteenth century, the British metal industries expanded rapidly; this was particularly evident in the iron industry, but copper, lead, tin and zinc industries also expanded. Table 6.3 illustrates the nature and rate of advances in the development of metal manufacturing and if it is looked at in concert with Table 6.2 (developments in steam power) it would seem that the metal industry were quite remarkably quick to exploit steam power - indeed it could be argued that in some cases the metal industry was the driving force for advances in engines. Certainly the developments of these two areas were very closely inter-woven.

Given that construction of the Metal Mills in Portsmouth Dockyard started in 1802, less than 10 years after updating of the Smiths workshops, and the plans for those Mills were expanded three years later in 1805 to incorporate the re-cycling of copper sheathing on a Navy-wide basis it would be difficult to draw any conclusion other than that Portsmouth Dockyard was very much at the forefront of the application of new technologies in the metal area. Whilst its involvement in "re-cycling" may have owed more to "necessity" than to progressive management strategy that does not detract from the fact that the width of Portsmouth's investment in the new metal technologies was impressive.

TABLE 6.3 - DEVELOPMENTS IN THE "METAL" AREA

YEAR	DEVELOPMENTS PRE 1790	YEAR	DEVELOPMENTS 1790 - 1816>
1700	Reverberatory Furnace used for copper/lead/tin production	1790	Iron begins to be used by civil engineers
1707	Abraham Darby patents mould boxes for foundry work	1792	Iron chain cable making machinery introduced
1709	Use of coke for iron-making, Abraham Darby	1792	John Wilkinson's patent for steam powered rolling mill
1745	Polhem's grooved rolls, Sweden	1794	Wilkinson's patent for Cupola furnace for foundry work
1750	Crucible process for making Steel - Huntsman	1800	Metal replacing wood for making machine tools
1750	Brass used for scientific instrument making	1803	Portsmouth Metal Mills - furnace for melting Copper
1757	Wilkinson's patent for furnace bellows	1805	Portsmouth Metal Mills - rolling machinery for Copper
1761	Low Brothers stamping & potting process	1805	Portsmouth Metal Mills - additional furnace for refining Copper
1766	John Purnell's patent for grooved rollers	1808	Improvements to Iron chain cable by Captain Sir Samuel Brown
1766	Cranage Brothers use of reverberatory furnace for iron	1808	Iron chain cable for anchors produced at Portsmouth
1767	Cast Iron rails produced at Coalbrookdale	1810	Foot-operated turning and screw-cutting lathes - Maudslay
1768	Smeaton's blowing cylinders for blast furnace	1814	Machine for planning metal - Matthew Murray
1770	Coke has replaced charcoal in ironmaking processes	1815	Three-high rolling mill introduced
1774	Patent for horizontal boring mill - Wilkinson	1817	Machine for planing metal - Richard Roberts
1774	Royal Navy introduced Copper sheathing for ships hulls	1832	Nasmyth's steam hammer introduced
1776	Steam powered blowing cylinder - Wilkinson	1839	Joseph Hall's `wet' puddling process
1779	Bridge at Ironbridge built	1856	Bessemer converter introduced
1779	James Keir's compound metal	1866	Siemens and Martin's open hearth process
1782	Steam powered tilt hammer - Wilkinson		
1783	Peter Onions use of reverberatory furnace for iron		
1783	Cort's patent for rolling iron bars		
1784	Cort's puddling process for iron production		
1787	William Purnell's patent for rolling iron bars		

Note: Bold & Underlined = Application in Portsmouth Dockyard

6.7. Fibre: The introduction of "new" technology into the textile industries and in particular cotton is inextricably linked with the Industrial Revolution and all the well known innovations in spinning and weaving by machines and the application of first water and then steam power to the making of cotton are very well documented. However wool, and flax for making linen, were more difficult to mechanise and thus innovations in their areas developed more slowly as the problems facing them took longer to overcome. Indeed the first patent for a spinning machine for flax was not taken out in this country until 1815 - around 50 years after Hargreaves's Spinning Jenny was invented. As there are similarities in the characteristics of hemp with flax, the two fibres would have been similar in the development of their manufacturing processes. There is very little information on the making and supply of canvas, but the Admiralty's system obviously worked well and it was unlikely that any serious consideration was ever given to producing canvas within the Royal Dockyards where space was always at a premium. There would have been little to spare for the necessary spinning and weaving sheds or the associated storage space for raw materials and finished canvas. Indeed sailmaking was to remain a hand craft into the twentieth century in spite of the invention of sewing machines in the 1850's.

With any fibre based product, there are a number of stages in the manufacturing processes where machines could be used rather than hand skills. Although the examples familiar to most of us are from the cotton industry[70], there are 3 areas which need to be considered in the manufacture of cordage - preparation of the fibre, spinning the yarn and making up the cordage itself. To prepare any fibre for spinning, it is cleaned and then combed until the fibres are lying parallel to one another. This was fairly easy to achieve with cotton which has a short staple[71] and only has to be combed in one direction. Wool[72], flax[73] and hemp[74] were far more difficult to prepare and thus a more difficult process to mechanise because they needed to be combed in both directions as the fibres did not have an even thickness.

Furthermore, as hemp had a very long staple - about three feet - it was both easy and economic to spin manually. This remained the normal way of spinning into the 1860's[75] and did not generally disappear until the early 1900's - in fact it can still be found in a few small roperies today. Mechanisation of spinning for ropemaking only really began to make headway with the introduction of different fibres[76] such as manila, coir and sisal during the nineteenth century.

6.7.1. Powered Ropemaking Machines: There were a number of attempts to introduce machines and a power source into ropemaking and Grimshaw is credited with building steam powered ropemaking machinery in 1790 although the degree to which it was used for forming the rope is unclear. As we have seen in Chapter 5, this process consisted of twisting yarn into strands, strands into hawsers and finally hawsers into cables. Each stage has more 'threads' to be twisted together and the product becomes larger in circumference and heavier. A patent[77] by Edmund Cartwright - better known for a power loom for weaving cotton - was taken out in 1792 for a ropemaking machine with Cordelier. This machine was able to maintain the opposite turning twists in each constituent element of the rope during spinning and the idea was widely adopted.

The Navy Board and the Royal Dockyards considered and tested a number of ideas which were suggested to them, these included, in 1793, Huddart's register plate and forming tube[78], ropemaking machines from Belfours[79] and Seymour[80] and later Goodrich and Maudslay's forming machine for Chatham. Captain Joseph Huddart was a senior and experienced commanding officer with the East India Company and therefore had practical experience of the problems of wear and tear on ropes. His register plate and forming tube[81] were designed to overcome the problems of the uneven tension on internal and external strands in a rope which caused them to break. Huddart's approach was to put rotating bobbins of yarn on a bobbin bank and pass the yarns through a pierced plate ahead of a forming tube where they were compressed. This process allowed an even tension to be maintained on all the yarns which increased the quality and working life of the rope.

It must be said that Huddart's idea was initially rejected both by the East India Company and the Admiralty[82] and therefore it does not seem surprising that there was little interest from other ropemakers at that time. However, after the expiry of his patent the idea was successfully adopted in the latter half of the first decade of the nineteenth century.

Benjamin Seymour's ropemaking machines were horse-powered, and they were given trials in the Dockyards[83]; three cables were made using unskilled labourers rather than skilled ropemakers. The Portsmouth Yard officers who saw these trials were undecided about their merits, and had reservations about Seymour's working methods but they did suggest further trials which should be attended by the Master Ropemakers.

The Yard officers were more impressed with John Belfours' machine when they had seen it in operation in June 1799[84] and agreed that it was suitable for making the same types of rope which had been specified in a Navy Board warrant of 28 May 1799. Machines of this type were subsequently fitted at Deptford[85] in the early years of the nineteenth century. They do not appear to have been a success, as they were replaced by Huddart's machines which were used until 1855.

The forming machine made by Maudslay in 1811 still exists in the Ropery at Chatham[86] but it is unclear if Goodrich actually designed the machine, although he was instrumental in its production. This forming machine could make six strands at a time and was driven down the ropewalk by a loop of rope taken round a capstan at one end of the building[87]. Today it can still be seen in use although an electric motor has taken the place of the capstan.

There were several attempts to apply steam power to the ropemaking processes Proposals by Bentham in 1802 for a steam powered ropery at Woolwich[88], fitted with machines designed by James Grimshaw of Sunderland, had been planned for three years when the Navy Board ordered work to cease until further orders[89]. No reason for the decision is given, but on 20th July the Admiralty had informed the Navy Board of Bentham's imminent visit to Russia[90]. This quixotic decision by the Navy Board merely adds fuel to the argument for a lack of support for technical innovation on the part of the Navy Board.

6.7.2. Rationale for NOT using Power: Table 6.4 shows the degree of technical progress in the Fibre area and it also shows the total lack of application of them in Portsmouth Dockyard. A number of reasons for this can be advanced.

6.7.2.1. The "Fire Risk" factor. This would seem a very understandable reason for the general caution in the application of steam power to Roperies given, as we have seen, that Portsmouth had had three major fires[91] in the Ropeyard in *less than 30* *years*. Ropemaking was a particularly "high fire risk" process since hemp, if too tightly packed and damp, will spontaneously combust; so correct storage of raw materials was essential. Furthermore ropemaking used highly inflammable substances like Stockholm tar - a by-product of the Scandinavian wood industry - as a preservative for the yarn. Significantly steam power was not applied to Chatham; probably the most innovative of the Dockyards in ropemaking until 1836[92]. It is uncertain whether Portsmouth ever used it although Henry Lewis in his description of the Dockyard in 1854 mentions a 6hp engine used for tarring the hauls of yarn, the date of which is unclear.

6.7.2.2. Management Strategy. - There might have been a conscious decision by the Navy Board to establish another yard (Chatham) as the "Lead Yard" in the rope area in a similar manner to Portsmouth's position in the "Metal Area". This would have made good sense especially as the workload on the Thames Yards was reducing due to problems getting ships in and out of them. Consequently, there would have been labour readily available to Chatham to fuel an expansion and offset a rundown in the Dockyard's standing.

The idea of Portsmouth looking to external sources for much of its rope requirements was already well established by 1805. As was shown in Chapter Five (5.8.2.2) its 1805 ropemaking output (1,633 tons) was above that of Woolwich (1,190 tons) but below that of Chatham (1,938 tons) and Plymouth (2,120 tons) with Contractors supplying 7,696 tons. At 13% of the total, Portsmouth would have had to go outside its own resources for much of its rope as it refitted some 42% of all ships being refitted in Britain in that year. Given that this was a management practice which appeared to be working it would seem illogical to invest both finance, and more especially space and people, in building up alternative supply sources within Portsmouth Dockyard.

6.7.2.3. Personality Considerations - Within Portmouth Dockyard Management it is reasonable to suggest the recent history of fires would not have put the Master Ropemaker in a strong position, when it came to arguing for new resources whilst, as suggested in 6.7.2.2, the situation might have been very different for his opposite number at Chatham. More significantly the "Men of Influence" in London may well have had their own priorities for developments, quite apart from which they might well have been reluctant to see Portsmouth grow even more into a "Super Yard" with all the attendant management risks that might bring. Not least of these might have been that the Dockyard Management might become more powerful than the Navy Board would like; a "Head Office" type attitude which has certainly been in evidence in Whitehall this century.

Whilst it is tempting to select 6.7.2.2 as the most acceptable of these hypotheses it would be wrong to casually discard the idea that the "Personality" factor might have been the more likely reason.

Whatever the reason Portsmouth Dockyard can have no claim to a place in the history of the applications of new technology in the Fibres area across the period 1790 - 1815.

TABLE 6.4 - DEVELOPMENTS IN THE "FIBRES" AREA

YEAR	DEVELOPMENTS PRE 1790	YEAR	DEVELOPMENTS 1790 - 1816>
1733	Kay's flying shuttle	1790	Grimshaw's steam powered ropemaking machinery
1764	Spinning Jenny, *hand powered* - Hargreaves	1790	*Woolcombing machine - Edmund Cartwright*
1769	Arkwright's water frame for spinning cotton	1792	Patent for ropemaking machine with cordelier - Cartwright
1779	Crompton's Mule -fine, strong warp thread for cotton weaving	1793	Register plate & forming tube - Joseph Huddart
1784	Horse powered ropemaking machinery - Seymour	1793	Belfours' ropemaking machines
1785	Introduction of steam power to cotton industry begins	1801	Patent for preparing - heckling - Flax, Thornton
1787	Cartwright's steam *powered loom for making cotton*	1809	*Machine for heckling Flax* - Matthew Murray
1788	Water powered mill for making Linen, Marshalls of Leeds	1810	Spinning linen thread with water frame
		1811	Forming machine for Chatham Ropery, Goodrich/Maudslay
		1812	Machine for spinning Flax - Philippe Girard, France
		1814	Girard's machine patented in Britain
		1815	John Lewis *rotary shearer for woollen cloth*
		1824	Spinning mules used in woollen industry
		1830	Chainstitch sewing machine - Thimmonier, France
		1832	Power looms used to make woollen cloths
		1846	First sewing machines - Howe, USA & Thomas, UK
		1851	*Lock stitch sewing machine Isaac Singer, USA*
		1862	Machines to spin Hemp - John Good, USA

Note: Bold & Underlined = Application in Portsmouth Dockyard

6.8. Wood: As we have seen wood was the material used in the greatest quantities by an eighteenth century dockyard. Wood had been used to provide shelter, transport and many everyday items since the dawn of history. By the eighteenth century both the skills of the craftsmen and the tools used had evolved for different crafts and trades - for example there were different types of adze, each adapted to the particular needs of the shipwright, wheelwright, cooper or carpenter using it. Many wooden items were produced by local craftsmen as and when they were needed. There was thus little incentive to mechanize working of wood, unless large quantities of nearly identical items were needed.

The way "mechanisation" could be applied to woodworking varied across the range of tasks involved but power could be harnessed only to woodworking in one of two ways - either rectilinear - in a straight line, or circular. Planing required rectilinear, boring needed circular motion and drilling a combination of both although sawing could use either rectilinear or circular motion,

In rectilinear movement, only one part of the sequence is "powered"; the recovery part of the movement is not. For example, the blade of a plane is set so that wood is removed from the surface on the forward movement only; the plane must then be returned to the beginning of the work for the next powered stroke.

With traditional hand woodwork the object to be worked on was held steady with the craftsmen applying the tool to it. However, with mechanized tools in this period the tool was fixed and the work was moved onto it. Lastly the introduction of power generally demanded that there be a means of stopping the machine when the piece of work was completed so that the machinery was not damaged by running too fast without a load. The subsequent history of the introduction of mechanisation and power into woodworking is largely recorded in terms of factories in which a number of different woodworking processes were carried out together on the same site. Nevertheless the records show that the basic processes of sawing, turning/planing and drilling/boring were all mechanised, in one degree or another, prior to 1793.

6.8.1. Sawing: One of the earliest uses of mechanization was in sawing wood since the preparation and cutting into planks of timber ready for use employed many men doing hand work. Sawmills powered by wind or water had been used on the Continent of Europe since medieval times[93] but attempts to introduce mechanical sawing into Britain in 1663 and again a century later in 1767 were unsuccessful due to the hostility of the sawyers who were afraid of losing their livelihoods[94].

Where the rectilinear motion of a saw was required (as one uses a hand saw), one saw blade could be used on its own, or several were set in parallel in a frame, although in this arrangement the frame was more likely to be used for up and down movement. The saw frame powered by a water wheel or steam engine, slides up and down in a second vertical frame in the same way as a sash window does (Figure 6.4), The timber was advanced to the saw on a horizontal frame which fitted through the vertical saw frame[95] and a rack and pinion used to move the horizontal frame forward.

The circular saw had been in use by clock and watch makers since the middle of the seventeenth century and in the 1770's a circular saw, for making wooden blocks, was introduced by the Taylor family - the Navy's chief contractor for blocks. The saw, a small disc with teeth round its circumference can be seen in a portrait of Walter Taylor[96], thought to have been painted in the 1780's. There were two primary options for installing a circular saw. It could be mounted on a bench with belt drive (Figure 6.4.1) to give it motion placed under the bench or it could be mounted on a moving overhead arm and raised and lowered at need, as in Brunel's saw for the Wood Mills at Portsmouth[97].

6.8.2. Turning and Planing: The principle of turning on a lathe is ancient. There were two types of lathe used for wood, the pole and the wheel lathes. The pole lathe where the work is rotated by a string attached to a foot treadle is a simple machine made from easily obtained materials and it could be used either in a workshop or in the open air. The foot treadle to provide power leaves both hands free to control the tool being used to shape the wood, and can provide different turning speeds as required. Lathes could also be turned with a wheel like that used on a spinning wheel, a loop of cord went round a second wheel on the same spindle as the wood to be turned and the larger wheel was turned by a handle.

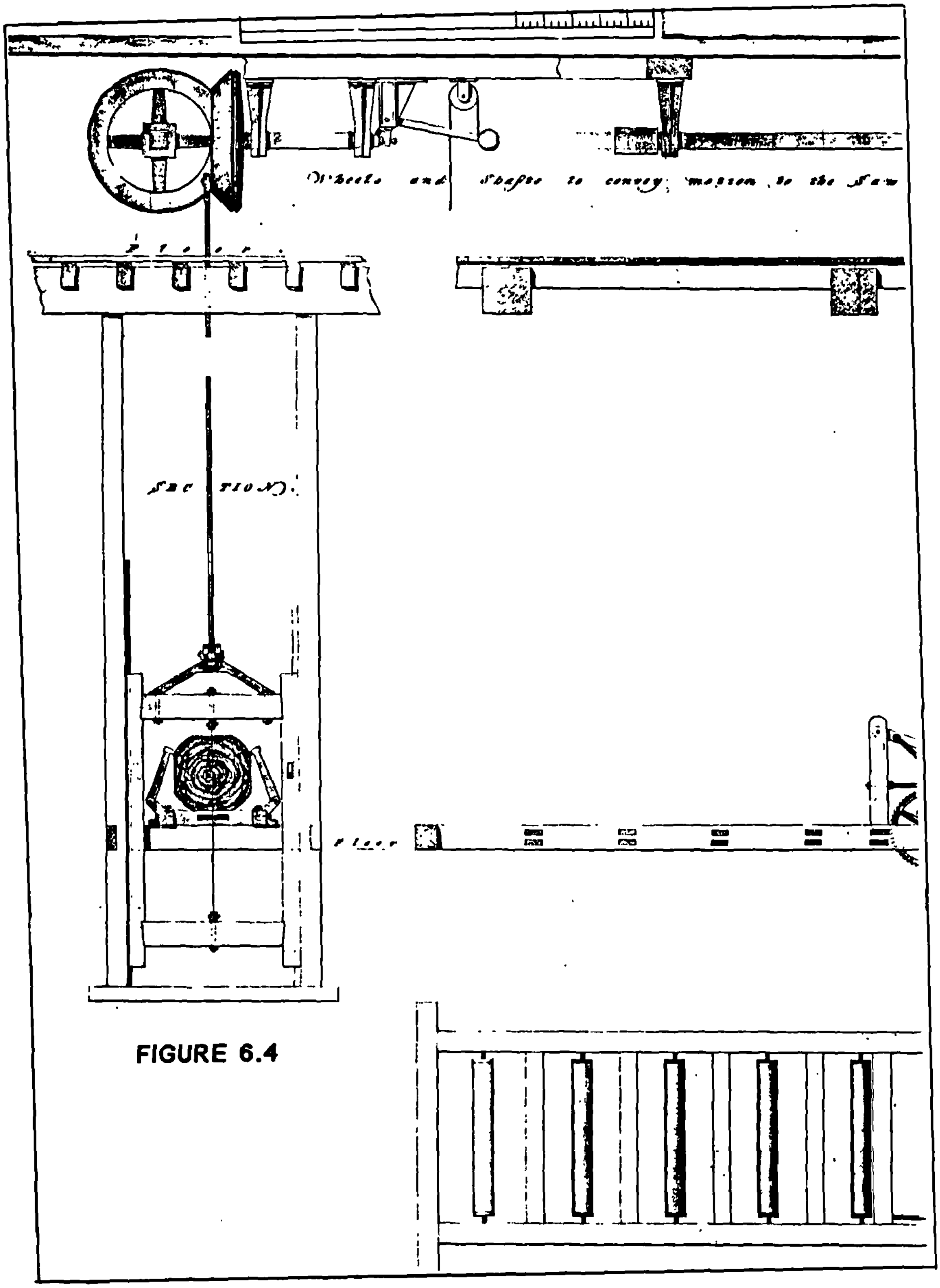
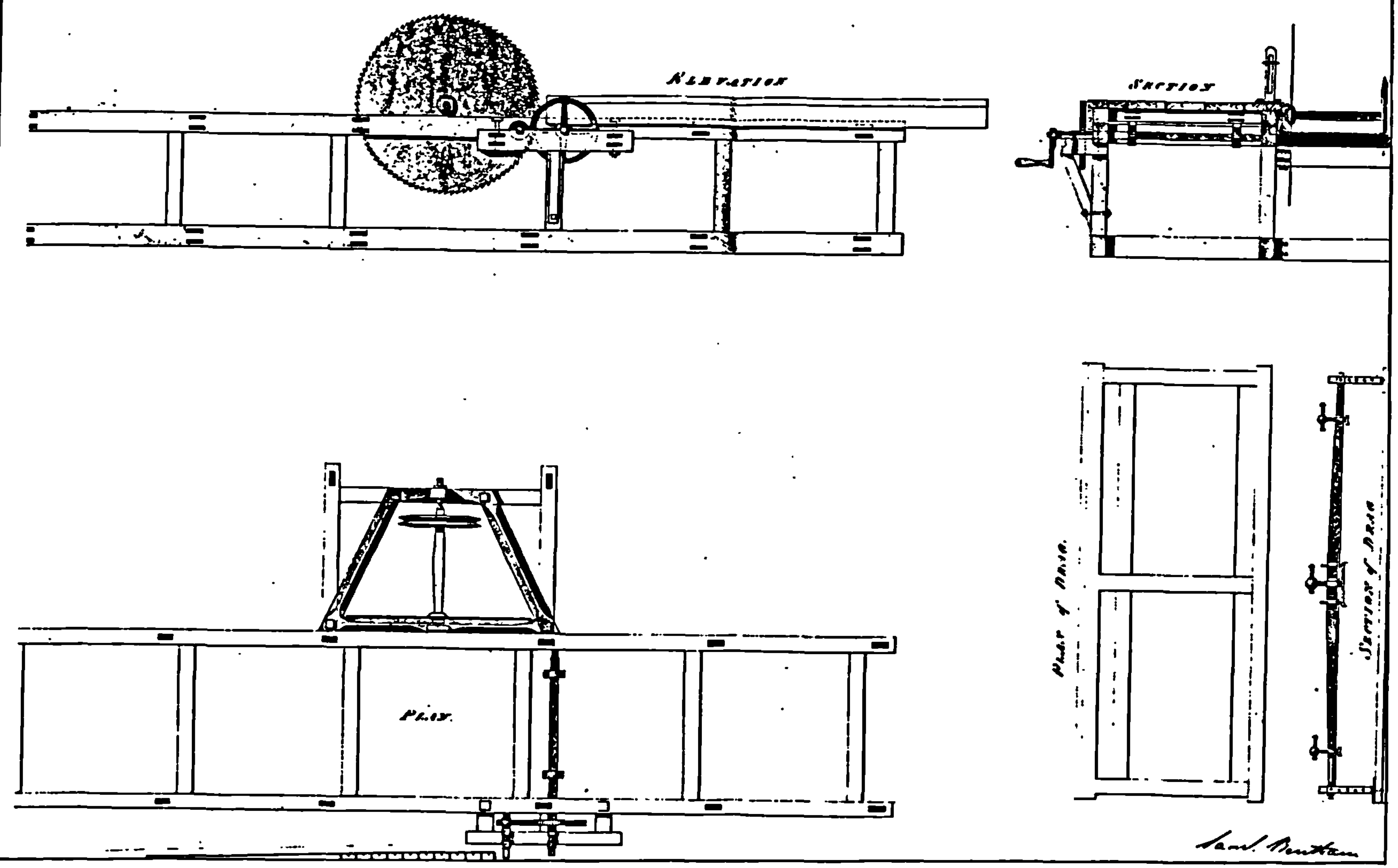

Wheels and Shafts to convey motion to the Saw
Floor
SECTION.
Floor

FIGURE 6.4

FIGURE 6.4.1

PLAN and SECTIONS of a Circular Saw Engine for converting Scantlings, not exceeding seven feet in length, principally out of Slab, and Offal, for Pillars, Carlings, Ledges, Block-Shells, and other Articles.



By the middle of the eighteenth century there were small lathes designed to produce parts for clockmakers, which had tool-holding carriages giving greater accuracy to the work. In 1770, Jesse Ramsden devised a lathe[98] for making screws for instrument makers, this was a lathe made of metal to work metal as were those of the early nineteenth century like Maudslay's lathe of 1800[99].

The idea of a machine for planing really originates again with the working of metal rather than wood because the expertise of the late eighteenth and early nineteenth century made smoothing and finishing sheets of metal far more difficult than that of finishing wood where there were many different types of hand plane. However, there were some mechanical planes for wood and Samuel Bentham designed one during his years in Russia (1780-1791) but it is unclear if it was ever made[100]. A mechanical plane which was built, and used, was designed in 1802 by Joseph Bramah for the Ordnance Board for the manufacture of gun carriages by the Royal Arsenal at Woolwich[101].

6.8.3. Boring and Drilling: The terms "Drilling" and "Boring" appear to have been used interchangeably in the period with machines being, in general, developed for metalwork although small boring machines were used with wood for specific products. For instance the Taylors used a simple machine to remove excess wood from wooden pulley blocks and it would seem certain that machines which today would be classed as drills were an integral part of later powered Block Mills.

Large boring machines were used to make water pipes and parts for pumps. The object to be bored was firmly fixed and a rotating boring head advanced horizontally although initially the head tended to wander off the true line as it moved. However, Wilkinson's patent of 1774 solved the problem by mounting a bar on bearings at both ends of the object being bored and the cutters traversed along the bar thus giving a straight bore. This enabled Wilkinson to produce cylinders for Boulton and Watt's steam engines of a regular wall thickness.

6.8.4. Wood Mills: A "Mill" appears to have been the general name for a wood processing plant utilising a variety of machines, but in general, a relatively restricted output. One of the early examples was the Taylor's blockmaking mill at Southampton. This was followed by a steam powered block mill in Portsmouth Dockyard and thereafter the term "Wood Mill" appears to become more common as the range of uses for the products of the mill diversified.

6.8.4.1. Taylor's Block Mills: It would be fair to say that Taylor's block manufactury at Southampton was a model for what could be achieved in the mechanisation of woodworking during the eighteenth century. From their first entry into the business in the 1750's, the Taylor family planned and used machines as part of their manufacturing processes powered by horses and later water. Improvements in the design of blocks and accuracy of manufacture meant that Taylor's blocks were half the size of the traditional hand-made product. This reduced the weight on mast and spars considerably. The blocks were also more effective when used, and cheaper to make. Firstly because they used, block for block, only half as much raw material and secondly in their construction, they were produced largely by semi-skilled, as opposed to skilled, labour. Although they nearly had a monopoly in supplying blocks to the Royal Navy, the Taylor family were not the only firm using machines for the sawing, boring and turning processes. The firm of Dunstervilles in Plymouth also used machinery which was seen by Simon Goodrich during his visit in September 1802[102]. Indeed, it is possible that these machines were purchased for use in Portsmouth as a stop gap measure until the Block Mills, which took longer than planned to build, were in full production.

It seems ironical that the drive for building the Portsmouth Wood Mills appears to have been initiated by Bentham, via the Admiralty Board, following the rejection by Taylor of Brunel's design for the machinery which he had first offered to that firm before approaching the Admiralty. In fact the Block Mills, and their machinery, built for Portsmouth were actually produced to a later design by Brunel.

6.8.4.2. Brunel's Block Machinery - Portsmouth: Taylor's blockmaking machines were built with wooden frames, powered by horses or water and had stops and guides to ensure accuracy, the machines were used for a number of tasks on both blocks and sheaves and the rest of the operations were done by hand. Brunel's machinery has been described at length and in detail in the work of K.R.Gilbert[103] and Carolyn Cooper[104]. The machines were made of metal and driven by a steam engine through belts and lineshafting and were constructed between 1802 and 1808. The metal construction gave a greater robustness and rigidity to the machines and thus the ability to achieve precision work. Unlike Taylor's machines, each operation in making a block shell, sheave or its pin had its own specialist machine to perform one operation only, and the partially completed component was moved to the next machine for the subsequent operation. The only operations done manually were the final shaping of the block shell with a spoke shave and the assembly of block shell, sheave and pin. There were three series of identical machines to make blocks of different sizes - 4 to 7 inches, 7 to 10 inches and 10 to 18 inches long[105]. Figure 6.4.2 illustrates the range in size and complexity of some of the blocks to be found in HMS VICTORY.

6.8.4.3. Portsmouth Dockyard Wood Mills: In a letter dated 21 December 1797 to the Admiralty Board[106], Bentham suggested the use of machines which included reciprocating and circular saws and machines for planing, rebating and mortising which he had patented in 1791 and 1793. Although the machines were originally designed for manual operation, by 1797, Bentham was proposing to power them with a 12hp steam engine. Bentham's chief reason for this was ".... the substitution of the invariable accuracy of the machine to the uncertain dexterity of expensive manual labour"[107]. His ideas were accepted and the Portsmouth Dockyard Wood Mills were built between 1798 and 1802.

<u>6.8.5. Brunel</u>: Marc Brunel's skills as an engineer were brought to the attention of the Armed Forces due to his successful collaboration with Samuel Bentham over the blockmaking machinery. Concurrently with patents for circular saws and wood cutting machinery and setting up his own sawmills at Battersea, he produced designs and estimates for machines to make cask staves for the Victualling Board in 1807. A more successful venture was the design and erection of a steam-driven sawmill for the Gun Carriage

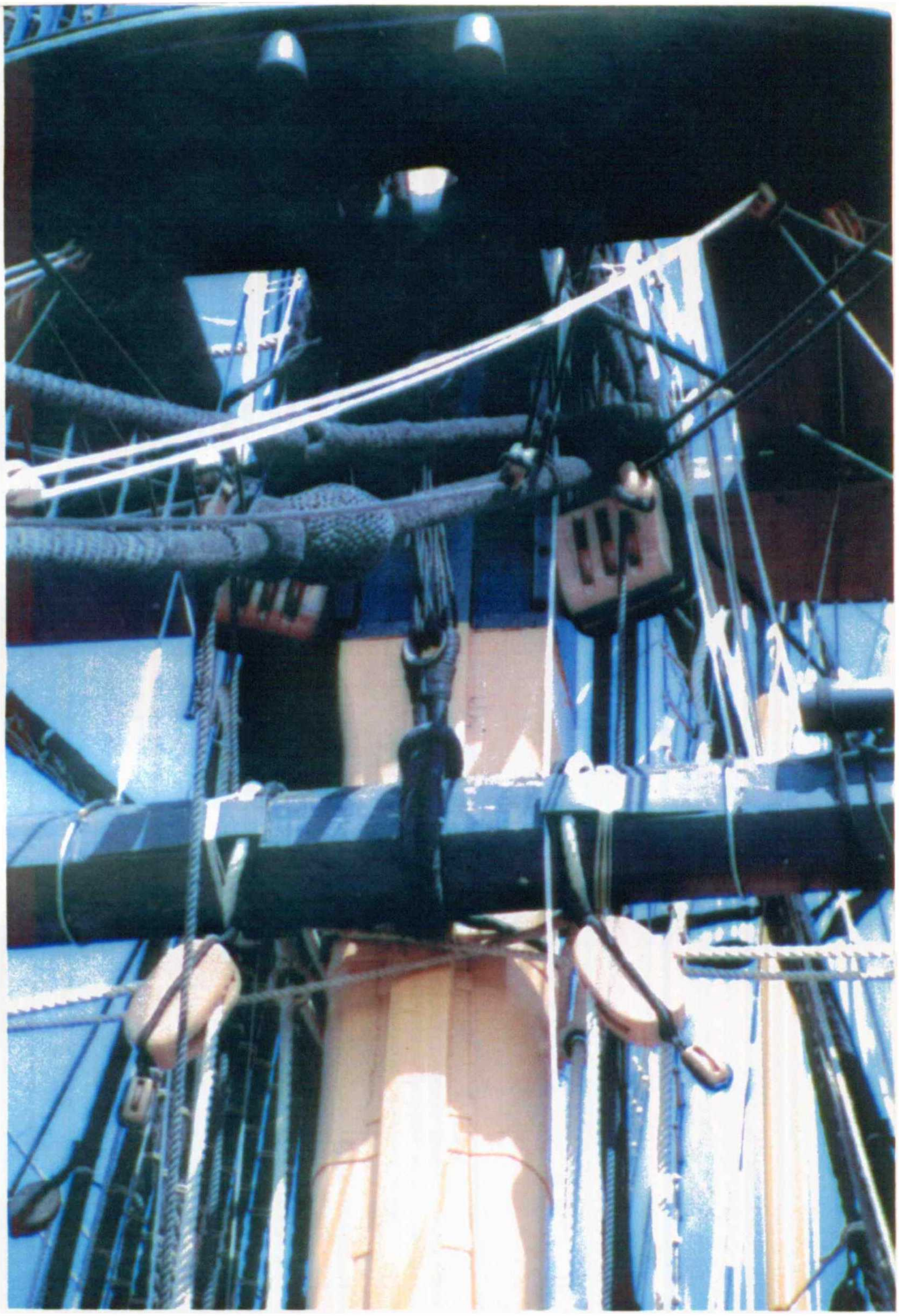
department at the Royal Arsenal, Woolwich on behalf of the Ordnance Board between 1808 and 1812[108].

In November 1811, Brunel, in a paper[109] to the Navy Board, detailed the costs and output for the six hundred Royal Dockyards sawyers as 66,000 feet of sawn timber per day. He went on to show how with four sawmills, each composed of eight saw frames - with an average of 36 saws per frame - an hourly output of 1,260 feet could be achieved which would meet all the requirements of Portsmouth, Plymouth, Chatham, Woolwich and Deptford. After amortisation of installation costs, 10% allowance for machinery depredation, and 13.25% allowance for running costs, a gross saving of £14,400 per annum would be achieved. The Navy Board was sufficiently persuaded by this to promptly enter into negotiations with him to proceed and install the requisite machinery at Chatham.

6.8.5.1.Brunel's Wood Mill - Chatham: It was in his approach to this task that Brunel moved the whole concept of power operated wood mills from just a factory process to a totally integrated development in which transportation and movement of raw and processed timber received as much attention as the sawing process itself. By exploiting the presence of a 38 foot high hill and sinking a huge 90 foot shaft to river level, he introduced a series of hydraulically operated inclined planes, iron railways and a large moveable crane with a huge arm. A 32 horse power steam engine pumped water around the system of balancing tanks and powered the sawmill of 8 frame and 2 circular saws where 10 or 12 men undertook the work processes which had previously employed 50 pairs of sawyers[110].

Although this ambitious project was not fully commissioned until 1816, it was still years ahead of its time. In the space of a mere 15 years, Brunel had advanced the 'bulk' processing of timber in this country from the 'status quo' of the previous 200 years to a highly manpower efficient and totally mechanised process. Whilst the transportation elements of his system were unique to the site at Chatham, other elements of the scheme were used in different Dockyards.

FIGURE 6.4.2



6.8.6. Basis of investment in Wood Machines: On the evidence it would seem entirely justifiable to suggest that Portsmouth Dockyard was very much to the forefront of the exploitation of new technology in the woodworking processes during our period which are summarised in Table 6.5. However it is particularly interesting to assess the driving forces behind this. - Three considerations initially stand out:

6.8.6.1. Bentham: The influence of Samuel Bentham with the Admiralty Board, and subservient to that, the Navy Board - albeit somewhat reluctantly, as some of its members were undoubtedly apprehensive about Bentham's high standing with the Admiralty.

6.8.6.2. Bentham and Brunel: The origins of the close working relationship between Bentham and Brunel are not clear but both men were entrepreneurs and first-class engineers at a time when the latter were a relatively small and select section of society and this must have played its part. More obviously they complemented each other's apparent ambitions. Bentham must have found Brunel's expertise of enormous value in pushing through his ideas for modernising the Dockyards and Brunel must have greatly valued Bentham's access to the Admiralty and his ability to promote Brunel's engineering designs into outright contracts and funding.

6.8.6.3. The Scale of Woodwork in Portsmouth: Lastly Portsmouth Dockyard was, on the evidence of Chapter Four, the Navy's biggest refitting yard and user of blocks and this would have made it a contender for the establishment of the Navy's first Wood and Block Mills.

6.8.6.4. Accidental Factors: All the above factors point to the influence of personalities being the dominant reason behind Portsmouth Dockyard's "primacy" in the exploitation of the new technologies in woodworking. Whilst that is undoubtedly true in part, there is strong evidence to suggest that a more immediate reason that Portsmouth Dockyard was so early in the field was very largely accidental. In 1795 Bentham succeeded in persuading the Admiralty, <u>in principle</u>, of the benefits to be obtained from introducing machines for woodworking but that body remained reluctant to authorise, and fund, an installation in a Royal Dockyard[111]. However, the Admiralty was content for Bentham to use his new machines, powered by a steam engine, as a trial during the construction of six experimental vessels he was under contract to build at Redbridge, not far from Portsmouth .

In the event the steam engine, designed by Sadler, was sufficiently delayed in construction that the opportunity to use the plant during the building of those ships, passed before the engine arrived in Portsmouth from where it was to be transported to Redbridge. Bentham therefore pressed the Admiralty to approve the installation of his machines and the steam engine in Portsmouth and approval was actually given in 1797[112] for what was to be the Portsmouth Wood Mill.

In other words the origins of Portsmouth Dockyard's early exploitation of new technology in the wood area owe as much to a "damage limitation" exercise on Bentham's part as they do to the Admiralty's commitment to this new technology and Portsmouth's requirements for it.

TABLE 6.5 - DEVELOPMENTS IN THE "WOOD" AREA

YEAR	DEVELOPMENTS PRE 1790	YEAR	DEVELOPMENTS 1790 - 1816
1663	First attempts to introduce sawmills in England	1793	**Patent for wood-working machinery (Portsmouth)- Bentham**
1754	Taylor's decision to use machinery for block making	1802	First rotary wood-planing machine - Bramah, Woolwich Arsenal
1767	Further attempt to introduce sawmills in London	1802	**Dunsterville's block machinery purchased for Portsmouth**
1770	Circular saw - Walter Taylor	1802	**Machinery for making blocks at Portsmouth - Marc Brunel**
1770	Royal Navy test Taylor's blocks	1806	Turning lathe for making treenails etc
1776	Patent for block manufacture - Elisabeth Taylor	1808	Patent for circular saws etc, Marc Brunel
1785	Bentham's design for wood planing machine while in Russia	1808	Brunel's steam driven sawmills, Royal Arsenal, Woolwich
		1811	Brunel's design for sawmill complex at Chatham

Note: Bold & Underlined = Application in Portsmouth Dockyard

6.9. Miscellaneous: Discussion under this heading, in this Chapter is limited to what can best be called "Services and Structures" in which technology in the period advanced significantly and played a major part in the business of the Royal Dockyards. Inevitably, other technological advances in the period will have been omitted in the interests of remaining within the finite limits of a thesis - both in terms of time and in terms of the size of the work itself. The exclusion of a particular item is therefore no reflection on its significance but results entirely from the author's view of its direct relevance to the potential of new technology in Portsmouth Dockyard between 1790 and 1815 and its interaction with advances in the primary work areas already discussed. The selected areas are:

Dry Docks - for refitting and fitting out of ships.

Dredging - of channels and dock approaches.

Sea Transportation - (in sheltered confined waters - NOT open seaways).

Services and Structures - Water, fire fighting and buildings (from the technical standpoint)

Land Transportation - as it could potentially apply within a limited industrial site.

6.9.1. Dry Docks: Throughout the eighteenth and early nineteenth centuries, the Royal Dockyards were enlarged and improved and the same was true of commercial docks and harbours as the rapid increase in the tonnage of merchant shipping created a demand for facilities to load and unload goods regardless of the state of the tide. Engineers like John Smeaton and John Rennie were involved with harbour works and the building of lighthouses. By 1800, the largest wet dock outside the Royal Dockyards was the Brunswick Dock, built for the East India Company at Blackwall on the River Thames in 1790 [113]. Associated with the wet dock were warehouses and bonded stores. This pattern of wet dock and warehousing was repeated in the docks built in the early years of the nineteenth century, notably the West India Docks in 1802, and the East India Docks in 1808[114] to serve London, but other ports such as Liverpool, Manchester, Newcastle, Bristol and Glasgow were also increasing and improving facilities.

As far as dry docks were concerned the Royal Dockyards inevitably led the way simply because the ships of the line were so much bigger and more sophisticated than the merchant ships of the period. The only possible exception to this generalisation were the ships of the East India Company and even they barely approached the size of third rates (74 guns). Portsmouth dry docks were expanded and updated between 1796 and 1803 under the direction of Bentham and this work included the introduction of caissons instead of the traditional lock gates. Further discussion of the detail of the complex and how it shared steam power for pumping with other new plant in the dockyard will be found in the next Chapter.

6.9.2. Dredging: The problem with dry docks is keeping the channels leading to and from them clear of silt and with a depth of water sufficient to enable ships to be warped in and out of them on a regular basis. Furthermore this requirement to maintain a given depth of water frequently extended right across a harbour or dockyard since the action of wind and tide tends constantly to move mud, sand and gravel into the channels through which ships must pass and up against the walls where they lie alongside. Wherever possible engineers utilised the natural water flow to scour out silt but in many circumstances it was also necessary to remove mud by mechanical means. Indeed, the difficulty of doing this in sufficient bulk was a constant problem for both the Admiralty and Commerce alike in the Thames Estuary. It was also a problem within Portsmouth Dockyard and particularly the approaches to the dry docks where regular dredging was essential.

At its most basic, dredging was done either by digging the silt out manually with spades at low tide, or by the use of scoops on long handles operated over the side of a boat. By the 1750's dredgers with several buckets or bags that could move round a frame or chain were in use in Sunderland harbour and under the aegis of Trinity House on the River Thames. The bucket chain either worked over the side of the dredger or through a central well in the hull and around 6 tons of mud could be raised in an hour from a depth of 10 feet by this means[115].

In 1780, the Hull Dock Company commissioned a horse powered dredger with eleven buckets on a ladder frame which could work at a depth of fourteen feet and raise 22 tons of mud per hour[116]. The first steam powered dredger, using steam to power the dredging operation, was introduced in Sunderland harbour in 1798. It was fitted with a 4hp Boulton and Watt engine which cost £390 and the mud raised was removed by a hopper barge; regrettably history does not record the hourly "lift" of this vessel. Nevertheless it appears to have been used for some time but the engine and hopper barge were sold in 1804 so it may not have been a great success[117].

Although Portsmouth was using a dredger of a similar type to Trinity House's, in April 1800[118], Samuel Bentham proposed to the Admiralty Board, the building of a dredger with steam powered machinery. This idea was accepted and the vessel was built in Portsmouth Dockyard at a cost of £1685[119] with its machinery being made in London. Its performance was impressive, as it was able to lift 80 tons of loose shingle an hour from a depth of 14 feet and it remained in service until 1816.

A second vessel for use at Woolwich[120] was subsequently built between September 1805 and April 1806 at a cost of £2986 and this had an even greater capability being able to work down to 21 feet and lift either 60 to 70 tons of gravel or 90 tons of mud per hour. This vessel appears to have had an even longer life since it was not withdrawn from service until around 1830[121].

6.9.3. Sea Transportation. Since Roman times, damaged or becalmed ships had been moved by towing with smaller boats and the effects that could be achieved were limited only by human endurance but the arrival of steam was to change this dramatically.

Early steam powered tugs had wooden hulls and paddle wheels. Initially designed for work on inland waterways such as lakes or canals, the tug quickly developed for use on tidal rivers and at sea. The first successful trial of a steam powered boat took place on a Scottish loch in 1788 when a steam engine, designed by William Symington, drove a paddle wheel positioned in the centre of the stern (transom). The same layout, but with an improved engine, was used for the 'Charlotte Dundas' which on the 28 March 1803 towed two 70 ton boats into a strong headwind for nearly twenty miles along the Forth and Clyde Canal in six hours[122].

The first tug to enter commercial service was the 'Industry' built in Glasgow in 1814 and she remained in service until the 1870's. Her design was different from that of the 'Charlotte Dundas' in that a single paddle wheel was fitted well forward on the centre line so that it 'pulled' the vessel along rather than 'pushing' it[123]. Within two years major ports like London, Liverpool and Newcastle had tugs in service.

Attempts were made to interest the Admiralty Board in the application of steam to power vessels. Charles, Earl of Stanhope undertook trials of a small vessel on the Thames during the 1790's[124]. Another attempt was a private venture by James Linaker, the Master of Millwrights at Portsmouth, whose plan is described in a letter of 4 July 1808 to Goodrich[125]. It appeared that a 2 hp steam engine was to drive two pistons which would force sea water through trunking and out at the stern - in effect this would, if successful, have pre-dated the "Pump engine/jet" we know today by 170 years. In a subsequent letter of 19 December 1808, Linaker told Goodrich that the Navy Board would not advance funds for the trial since they did not believe his concept was applicable to ships of war. However, he would do the trials at his own expense[126]. Most unfortunately any further correspondence on the subject has not survived and therefore the outcome of the trials is not known.

6.9.4. Water Supplies: Today, the vast majority of the population of Great Britain take the instant availability of water from the tap for granted. Two hundred years ago, the situation was very different with the majority of people depending on buckets to move the water from either a well, a pond or a river to where it was needed.

Piped water supplies had existed from Roman times but these were, in the main, dependent on some form of storage - be it a lake, pond or water tank (topped up by a horsedriven or waterdriven pump), positioned at a higher level than the outflows. For those people living and working in flat areas it was not until steam driven pumps were introduced at the turn of the eighteenth and nineteenth centuries that mains water supplies became a practicability. The New River Company was the first of London's great water supply companies and its aqueduct to supply the Round at Clerkenwell was formally opened in 1613. The company's first steam pump was installed in 1768 and by 1822 no fewer than nine separate water companies were supplying the needs of London while, at the same time, the arrival of steam pumps led to a major expansion of the water industry across the country.

In the immediate vicinity of Portsmouth Dockyard, the Portsea Island Water Company[127] was founded in 1808 to supply piped water in Portsmouth Town but it was in direct competition with the Farlington Water Company, also founded in 1808. This company drew its supply of water from the springs along the base of Portsdown Hill and used a 24hp Boulton and Watt steam engine and 28 miles of main and service piping to supply their customers in Portsmouth.

Until the establishment of these companies, Portsmouth Town depended for its water supply on springs and wells sunk into the sand/gravel strata. Portsmouth Dockyard was also subject to the same geological conditions which did not retain the water as well as some other materials and thus the supply was periodically threatened by droughts or lack of rain. It is not clear from the surviving records where the Dockyard's fresh water supply was located. Historians are at odds with each other on the subject since Roger Morriss says that Portsmouth had no natural fresh water supply[128] while R.J.B. Knight, writing about the Yard during the American War of Independence[129] says that supplies were usually adequate which suggests a nearby source if it is not within the Dockyard. According to the *London Journal*[130] of 7 September 1723 - "The dockyard by the late improvements is made the best in England, and from a well in the centre of the yard they are about to lay pipes to one of the Gitty[131] heads, where three longboats may come at any time of the tide to fill water:....." The existence of a well within the Dockyard is confirmed by Bentham's comment in a letter of 27 September 1801 which refers to " several wells at different parts of the Yard...". A plan enhancing any existing water pipes and storage tanks within the Dockyard was proposed by Bentham in a letter of 12 February 1797[132] for a ring fresh water system to provide for the needs of ships, the Dockyard and firefighting. Included in the scheme was a new fresh water well, which was completed and in use by 1801. Tanks to store water for everyday needs were used in the Dockyard as a Navy Board instruction of 30 June 1778 refers to water tanks to be built on the north side of the Ropehouse[133] whilst in 1791 the Yard officers sought permission to install a 50 gallon water tank to provide water for the smiths[134].

6.9.5. Firefighting: By the eighteenth century, mobile apparatuses to deal with fires were being developed; Richard Newsham patented a manually pumped fire engine in 1721, which was based on the principle of a pump. Along each side of the engine were handles and foot treadles which were operated by teams of men. The more men who could work, the greater the jet of water produced BUT the water had to be constantly replenished by buckets. Subsequently Newsham made six different sizes of improved fire engine, the largest of which could project 170 gallons per minute a distance of 40 yards[135]. In bucket terms, that equates to two three-quarters full two gallon buckets being provided at the fire engine every second. Not surprisingly; there were obvious attractions in having a ring main readily available. A further comment from Bentham's letter of 12 February 1797 about water for firefighting says "...by means of Engines used on such occasions...." which suggests that the Dockyard did have firefighting appliances at that date.

6.9.6. Buildings and Fire Precautions: By the end of the eighteenth century, manufacturers were having to take the potential dangers of the steam engine and the weight of the new machinery into consideration as well as traditional fire risks in building factories and workshops. Investigations by William Strutt in the 1790's into the problems of fires in cotton mills[136] initiated a wider use of brick as a structural material and the use of fire resistant cast iron in place of wood for internal elements such as supporting pillars and floors. These ideas were incorporated in his calico mill at Derby built in 1793. The first fully iron-framed building was a flax mill built at Shrewsbury[137], which was owned by Charles Bage who was a friend of Strutt.

The Dockyards were particularly aware of the hazards of fire with many of their structures, built in the seventeenth century, being of wood as well as being used to process or store combustible materials such as hemp, pitch, tar, or wood. The planned extensions to Portsmouth Dockyard, which were approved in 1760 and undertaken over the next 20 to 25 years, called for brick rather than wooden buildings to mitigate these fire risks. The beneficial effect of this policy was demonstrated when the fire of 1776 gutted the ropehouse, but did not spread to the adjoining buildings, unlike the fire of 1770, which had not only devastated the ropemaking facilities, but caused considerable damage in the centre of the Dockyard.

However the new brick storehouses, as well as the ropehouse and sail loft still had their internal floors, supporting columns and stairs made of wood[138] although during the 1780s, fireplates to inhibit the spread of fires in particularly vulnerable areas were introduced. These were probably made of cast iron or tin and were fitted under the floors of the storehouses, ropehouse[139] and the rigging house[140]. Portsmouth Dockyard's first 'fire-proof' structure, built of brick with cast iron vaulting, was the Pay Office built about 1808[141].

6.9.7. Railways: The eighteenth century saw developments in both the construction of coaches and wagons and in the road surface on which they were used. Typically these plateways, wagonways or tramroads were to be found where large quantities of coal or other minerals were moved from the colliery or quarry to a point of embarkation on a canal, river or the sea. Initially, the movement of loaded wagons along wooden, or cast iron rails was dependent on horses to pull the wagons but later stationary steam winding engines were introduced. It was not until Richard Trevithick invented the steam locomotive in 1804, that "mobile" power became available and the steam railway could take on the role of 'common carrier' of goods and people.

R.C.Riley writing about Portsmouth Dockyard says that "Given the unevenness of the roadways and the weight and quantity of materials moved within the Georgian Dockyard, quite apart from the presence of such clear-sighted men as Bentham and Goodrich, it may be assumed that some form of tramway must have existed[142]" but evidence to support this assertion has not come to hand.

Indeed there would have been major difficulties in using such a system in a Dockyard at this time. Firstly, the wagons of the period were tubs on wheels which, whilst being suitable for moving bulky minerals, were much less usable for timber where a flatter and longer wagon was needed. Secondly, the layout of the Dockyard was against the economical use of time and effort in running a tramway compared with moving lines of wagons from the point of loading to the point of delivery and back. The Dockyard would have needed to supply many different points all of which were relatively close together, unlike a colliery which needed just one or two lines between the loading point and a quayside, possibly at some distance.

However the Navy Board quite clearly accepted the principle of a tramway as Marc Brunel used a steam driven crane running on overhead rails to lift timber as part of the infrastructure for his sawmills at Chatham in 1812[143].

6.9.8. Roads: Side by side with the early phases of railways were improvements in the construction of roads, pioneered by men like Metcalf, Telford and Macadam who emphasised the need for good foundations and cambered, firm surfaces to improve drainage. However there is no evidence of such techniques being used in this period to improve the roadways in the Dockyards. It may well be, certainly in the case of Portsmouth, that the distances involved within the very restricted Dockyard site, did not appear to justify the expense. Or, more likely, the inevitable interruption to the daily work of the yard, whilst such work went on, was not acceptable in wartime.

6.9.9. Assessment of the "Miscellaneous" Area: In 1790, Portsmouth Dockyard was still in the process of implementing a large number of "services and structures" improvements which had been initiated in the 1760s as a result of earlier serious under investment in the Royal Dockyards being forcibly brought home to the Government of the day. With the outbreak of war in 1793 and the demand for the Dockyards yet again to expand the operational fleet as fast as possible it was natural that the ongoing improvement plan should be enhanced, expanded and extended. As a result, Portsmouth's applications of the emerging new technologies in the miscellaneous area, summarised in Table 6.6, was generally amongst the early investments and, in some cases such as in the dry docks and dredging, right at the leading edge of the new technologies.

Only in the transport area did the Dockyard, certainly in this period, not exploit the advances available. Whilst its lack of investment in rail or plateways would seem to be based on sound economics, its tardiness in recognising the benefits to be had from steam driven tugs does not ride well alongside its other enthusiasms for steam power. However it is most unlikely that a decision on whether to invest in steam tugs was taken at a level below the Navy Board and it is even more likely that it was taken at Admiralty Board level. Understandably that organisation could hardly have been expected to look favourably on an invention that potentially could (and did) challenge the supremacy of the world's largest sailing navy.

TABLE 6.6 - DEVELOPMENTS IN THE "MISCELLANEOUS" AREA

YEAR	DEVELOPMENTS PRE 1790
1750	Water balance for lifting coal, Co. Durham - Menzies
1750	Bag and spoon dredgers, Sunderland - R. Thames
1760	Building of Eddystone lighthouse uses cement - Smeaton
1776	Beginning of glass industry in St Helens
1780	Horse powered dredger for Hull Docks
1786	Albion Mills, London, iron shafting and gearing, John Rennie
1781	Steam driven waterwheel for Victualling Board - Smeaton
1788	Steam powered paddle wheel boat trialled in Scotland

YEAR	DEVELOPMENTS 1790 - 1816>
1790	Steam boat passenger service in USA
1795	Iron water trough & spans for Pontcysyllte aqueduct - Telford
1796	B&W 4hp driving ladle dredger in Sunderland harbour
1798	**<u>Docks - Caisoons replace lock gates at Portsmouth</u>**
1797	First iron frame building, main beams and joists of cast iron
1798	Gas lighting of Soho Works, Birmingham
1800	**<u>Apparatus for examining ship's keels - Robert Seppings</u>**
1801	Steam powered road carriage - Trevithick
1802	West India Docks begun, William Jessop, completed 1806
1802	Steam driven paddle wheel tug, Charlotte Dundas - Symington
1802	Horse-powered bucket ladder dredger, Brunswick Dock - Rennie

YEAR	DEVELOPMENTS 1790 - 1816> (Continued)
1803	**<u>Dredger - steam operated for Portsmouth Harbour</u>**
1804	Steam loco pulls 10 ton load on cast iron tramways - Trevithick
1804	Tramways in use in collieries on Tyneside and South Wales
1805	Surrey Iron Railway
1805	Cast iron columns and roofs for buildings, London Docks - Rennie
1805	**<u>Iron water pipe system for Portsmouth Dockyard</u>**
1806	**Second dredger built at Woolwich - for Deptford**
1806	Steam powered dredger at work at Ipswich
1806	Oystermouth Railway
1806	Gas lighting of factories begins
1807	Paddle steamer Clermont, B & Watt engine - Fulton, USA
1808	Iron rails in use by steam locomotives
1809	Pall Mall lighted by gas
1811	Bell Rock Lighthouse begun
1812	First European commercial steamship service, Comet - Henry Bell
1812	Hydraulic Jack
1812	Rack and pinion railway - Blenkinsop
1812	Plymouth breakwater begun - John Rennie
1813	Proposal for steam tugs - Brunel
1814	Paddle steamer 'Industry' of Glasgow in use as tug
1815	London to Holyhead road begun
1816	Maudslay's marine engines begin in service
1818	First open sea steam service, Glasgow-Belfast
1819	First west-east trans Atlantic steam crossing, SS Savannah
1821	First cross Channel steam service, Dover-Calais
1821	Steam ship with Iron Hull - Aaron Manby

Note: Bold & Underlined = Application in Portsmouth Dockyard

6.10. Overview of Available Technology with Dockyard Potential. It will be recalled that this Chapter set out to discuss the technological advances that came available during the period up to 1816 which had potential for application within Portsmouth Dockyard. Since the detail of those that were introduced into that Yard are discussed in greater detail in the next Chapter this Overview is biased towards summarising those advances which had potential but which were not exploited.

In the general area of the "lift and shift" of solid objects advances in the technology of the period generally involved static machines and machinery. However the primary dockyard requirements were for lift/shift right across the yard with very few fixed "high utilisation" lift points and therefore it would seem that it was sound economic sense for the Dockyard to continue with its range of purpose-built portable devices that met its many and varied requirements. In the area of lifting and shifting water the Dockyard's exploitation of steam pumping in the period was considerable (the details are discussed in the next chapter).

Portsmouth's exploitation of developments in the metal area was extensive and the substantial investment in re-cycling copper (and, on contract, wrought iron) could be envied by many of today's industrial plants. In the wood area the Yard also exploited a whole range of developments and in a number of them it led the way - not only in the Royal Dockyards but across the national industry as a whole. In the "miscellaneous" area it was also well to the fore with the exception of transport. Its lack of investment in railways/plateways would seem to be based on sound economics but the decision not to invest immediately in steam tugs must surely have been an Admiralty Board one - based possibly on "policy or strategic considerations" - a suggestion which actually may be both fairer and more accurate than just claiming that the Admiralty was driven in this matter purely by "conservatism" or "tradition".

The one major area in which Portsmouth totally failed to invest in new technology was "Fibre". The reasons for this are not clear and the possibilities include the Yard's fear of fire in the rope works, a sound management decision by the Navy Board to use some yard, other than Portsmouth as the "lead" yard in this area and for Portsmouth to rely on supplies from other sources. Lastly there could well have been a lack of influence on behalf of the senior fibre management within Portsmouth. Dockyard.

Across the whole of the technologies two things stand out as far as Portsmouth Dockyard is concerned:

The variety of activities in which Portsmouth was involved and the range of technical innovations introduced in the period was very large. It would seem doubtful if there were many, if any, other establishments in the country which invested in so many new advances in this period.

The name of Samuel Bentham comes up time and time again, both as an advocate for approvals and funds from the Admiralty and as engineering project manager. In addition, he even produced some inventions himself. The debt the management of that Dockyard owed to him in this period was immense. He may well not have been as gifted an engineer as Brunel but as a Project Manager, there are a great many areas in Defence today where he would be most enthusiastically welcomed.

1. Jonathan Coad, *The Royal Dockyards 1690-1850*, Scolar Press, Aldershot, 1989, page 226.

2. R.C.Riley, *The Industrial Archaeology of the Portsmouth Region*, The Portsmouth Papers No 48, Portsmouth, 1987, pages 6 and 14.

3. P.S.Christie *Occupations in Portsmouth 1550-1851*, unpublished MPhil thesis, Portsmouth Polytechnic, 1976, page 139.

4. ADM 1/3526, Letter of 10 July 1801, from Samuel Bentham to the Admiralty Board.

5. Coad, op. cit., n.1, p.274.

6. Paul N. Wilson, 'The Waterwheels of John Smeaton', *Transactions of the Newcomen Society*, (1955), 30, pp.35, 36, 38 and 41.

7. Barrie Trinder, (ed), *Blackwell Encyclopedia of Industrial Archaeology*, Blackwell, London, 1992. see Tide Mills.

8. Gordon Jackson, *The History and Archaeology of Ports*, World's Work Ltd., London, 1983, Illustration of Brunswick Dock, Blackwall, c. 1798, on page 55.

9. Goodrich Collection, B30, 11 October 1813.

10. Jackson, op. cit., n.8, p.98.

11. ADM 140/555/14,15,16 and 18. These are for the years 1790, 1793, 1796 and 1810.

12. In a treadwheel, the operator walks on boards on the inside of a large diameter wheel, in a treadmill, the operator walks on boards round the outside of a large diameter wheel. J.K.Major, 'The Horse Engine in the Nineteenth Century', *Transactions of the Newcomen Society*, (1998), 60, p.31.

13. I am indebted to my husband Captain M.J.M. Wilkin, Royal Navy for the information on how a capstan works.

14. John McKay, *The 100-gun Ship Victory*, Conway Maritime Press, London, 1987, page 13.

15. Ibid, p.14,

16. David Lyon, *The Sailing Navy List*, Conway Maritime Press, London, 1993, Pages xi-xv and 321 to 323.

17. E.A.Forward, 'Simon Goodrich and his work as an Engineer, Part 1, 1796-1805', *Transactions of the Newcomen Society*, (1922), 3, pp.2 and 3.

18. Brian Lavery, *The Arming and Fitting of English Ships of War*, Conway Maritime Press, London, 1987, pages 72-73.

19. Forward, op. cit., n.17, pp.2-3.

20. Adrian Jarvis, *Hydraulic Machines*, Shire Publications Limited, London, 1985, Volume No. 144, pages 2 and 3.

21. Richard L. Hills, *Power from Steam, A History of the Stationary Steam Engine*, Cambridge University Press, Cambridge, 1989, pages 31-51.

22. Ibid, pp.31-51.

23. Jennifer Tann, 'The Steam Engine on Tyneside in the Industrial Revolution', *Transactions of the Newcomen Society*, (1992), 64, table on p.71 and 'Riches from Copper: the adoption of the Boulton and Watt engine by the Cornish mine adventurers', *Transactions of the Newcomen Society*, (1995), 67, table on p.30.

24. Hills, op. cit., n.21, pp.51-70.

25. Lance Day and Ian McNeil, (eds), *Biographical Dictionary of the History of Technology*, Routledge, London, 1996, pp.714-715, entry on Richard Trevithick.

26. ADM/Q/3322, Letters of 4 July and 24 November 1803.

27. Donald S.L. Cardwell, 'The Age of Steam Power', *A281,Technology and Change 1750-1914*, Open University Press, London, 1983, pages 75-77.

28. Neil Cossons, *The BP Book of Industrial Archaeology*, David and Charles, Newton Abbot, 1993, Third edition, pages 81-82.

29. Hills, op. cit., n.21, pp.64-69.

30. Cossons, op. cit., n.28, p.65.

31. Tann, op. cit., n.23, pp.69-70.

32. Hills, op. cit., n.21, p.72.

33. Annual estimates are discussed in Chapter 2, page 18.

34. ADM/Q/3320, Letter of 1 July 1799.

35. Lavery, op. cit., n. 18, p.49.

36. Coke is coal which has been heated strongly to drive off the sulphur which made iron brittle and therefore unsuitable for forging.

37. T.K.Derry and Trevor I.Williams, *A Short History of Technology*, Oxford University Press, Oxford, 1970. page 478.

38. Patent No. 1420, 12 June 1784.

39. Letters from Portsmouth Dockyard officers to the Navy Baord for June 1784 to July 1786 are missing.

40. R.A.Mott, 'Dry and Wet Puddling', *Transactions of the Newcomen Society*, (1977), 49, p.154.

41. Mott, op. cit., n. 40, p. 154.

42. H.W.Dickinson, 'Henry Cort's Bicentenary', *Transactions of the Newcomen Society*, (1940), 21, pp.31-39.

43. W.R. Morton and N.Mutton, 'The Transition to Cort's Puddling Process', *Journal of the Iron and Steel Institute*, (1967), 205, pp.722-727.

44. Mott, op. cit., n.40, pp.153-158.

45. POR/D/27, Letter of 12 July 1796.

46. POR/D/27, Letter of 30 November 1796.

47. POR/D/27, Letter of 16 December 1796.

48. Isaac Wilkinson, No 565 in 1738 and No 713 in 1757, Joan Day and R.F.Tylecote, (eds), *The Industrial Revolution in Metals*, The Institute of Metals, London, 1991, page 213.

49. Forward, op. cit., n.17, pp.10-12.

50. Roger Morriss, *The Royal Dockyards during the Revolutionary and Napoleonic Wars*, Leicester University Press, Leicester, 1983, page 60.

51. Derry and Williams, op. cit., n.37, p.478.

52. W.K.V. Gale, *Iron and Steel*, Ironbridge Gorge Museum Trust, London, 1979, page 12.

53. Abraham Rees, (ed), *Rees Manufacturing Industries,* Longmans, London, 1819-20, reprinted by David and Charles, Newton Abbot, 1972, edited by Neil Cossons, volume 4, pages 323 - 329.

54. Ibid, v.4, pp.323-329.

55. Rees, op. cit., n.53, v.4, pp.325-326.

56. Goodrich Collection, B16, 18 December 1806, Account of Goodrich's visit to Fontley.

57. Colin Chant, 'Iron and Steel', *A281 Technology and Change 1750 - 1914,* Open University, Milton Keynes, 1983, Figure 5, page 32.

58. Rees, op. cit., n.53, v.4, p.324.

59. Morriss, op. cit., n.50, p.49 and Forward, op. cit., n.17, p.10.

60. Cossons, op. cit., n.28, p.114.

61. *Guide book for Blists Hill Open Air Museum,* The Ironbridge Gorge Museum Trust Ltd and Jarrold Publishing, London, 1995. page 15.

62. POR/D/29 Letter of 15 April 1813 from William Kingston to the Navy Board.

63. POR/D/29 Letter of 24 November 1812, gives the composition of mixed metal as 12 lbs pure Copper, 1 lb grain Tin and 3/4 lb commercial standard Brass.

64. POR/D/29 Letter of 2 June 1813 from Hamlet Vernon to the Navy Board.

65. Forward, op. cit., n.17, p.11.

66. Day and McNeil, op. cit., n.25, p.509.

67. Ibid, p.607.

68. Cossons, op. cit., n.28, p.139.

69. Derry and Williams, op. cit., n.37, p.488.

70. Derry and Williams, op. cit., n.37, pp.558-566.

71. The Staple is a graded fibre of cotton, wool or flax.

72. There were several attempts to mechanise wool-combing including one by Edmund Cartwright, but the problems were not finally solved until the 1850's. Christopher Harvie, 'Technological Change in the Textile Industries', *A281 Technology and Change 1750-1914*, Open University Press, London, 1983, page 18.

73. Machines to heckle flax were invented by Matthew Murray in 1809, and Philippe de Girard 1810 to 1832. Day and McNeil, op. cit., n.25, pp.509 and 290.

74. Preparation of Hemp was not mechanised until the 1860's. Richard Holdsworth and Brian Lavery, *The Ropery*, Visitors handbook, Historic Dockyard at Chatham, Jarrold Publishing, Norwich, 1991, page 8.

75. Mechanical spinning was introduced at Chatham in 1864. Ibid, p.9.

76. H.W.Dickinson, 'A condensed history of Ropemaking', *Transactions of the Newcomen Society*, (1942), 13, pp.78-79.

77. Day and McNeil, op. cit., n.25, p.133, Patent No. 1876, 15 May 1792,

78. Patent No. 9512, 25 April 1793.

79. There were three patents - No.1939 of 16 March 1793, No. 2223 of 3 May 1798 and No.2313 of 3 April 1799.

80. Patent No. 1442, 3 July 1784.

81. Dickinson, op. cit., n.76, p.76.

82. ADM/Q/3322, Letter of 19 April 1804.

83. POR/D/26, Letters of 1 May, 7 and 12 June and 23 August 1792.

84. POR/D/27, Letter of 8 June 1799.

85. Dickinson, op. cit., n.76, p.76.

86. The Ropery in the Historic Dockyard at Chatham is a commercial venture as well as giving displays for visitors.

87. Holdsworth and Lavery, op. cit., n.74, p.13.

88. E.A.Forward, 'Simon Goodrich and his work as an Engineer, Part II, 1805-1812', *Transactions of the Newcomen Society*, (1938), 18, p.4.

89. ADM/Q/3323, Letter of 22 July 1805.

90. ADM/Q/3323, Letter of 20 July 1805.

91. Coad, op. cit., n.1, pp.204-206.

92. Holdsworth and Lavery, op. cit., n.74, p.5.

93. Derry and Williams, op. cit., n.37, p.253.

94. Samuel Smiles, *Industrial Biography - Iron Workers and Tool Makers*, Reprint of 1863 edition by David and Charles, Newton Abbot, 1967, edited by L.T.C.Rolt, page 165.

95. Rees, op. cit., n.53, v.5, pp.442-443.

96. J.P.M.Pannell, 'The Taylors of Southampton: pioneers in Mechanical Engineering', *The Institute of Mechanical Engineers,* (1955), Figure 7 - the original portrait is in the possession of Southampton Corporation.

97. Abraham Rees, (ed), *Cyclopaedia*, Longman, London, 1819, Plates Volume 2, Machinery, Plate 1.

98. Derry and Williams, op. cit., n.37, p.346.

99. Ibid, p.348.

100. M.S.B. 'The Invention of Wood-cutting Machinery - Sir Samuel Bentham and Mr Brunel', *Mechanics Magazine,* (1852), 56, no. 1496, p.265. M.S.B is Maria Bentham, wife of Samuel Bentham.

101. Derry and Williams, op. cit., n.37, p.354.

102. Carolyn Cooper, 'The Portsmouth System of Manufacture', *Technology and Culture*, (1982), 25, p.188.

103. K.R.Gilbert, *The Portsmouth Blockmaking Machinery*, Her Majesty's Stationery Office, London, 1965.

104. Carolyn Cooper, 'The Production Line at Portsmouth Block Mill', *Industrial Archaeology Review*, (1981), 6, no 1, pp.28-43 and op. cit., n.96, pp.182-225.

105. Gilbert op. cit., n.103, pp.5-6.

106. ADM 1/3525, Letter from Samuel Bentham to the Admiralty Board.

107. ADM 1/3525, Letter of 21 December 1797 from Samuel Bentham to the Admiralty Board.

108. Richard Beamish, *Memoir of the life of Sir Marc Isambard Brunel*, Longman, London, 1862, pages 100-122.

109. Ibid, pp.106-107.

110. Beamish, op. cit., n.108, pp.108-111.

111. M.S.B., op. cit., n.100, p.266.

112. ADM 1/3525, Letter from Samuel Bentham to the Admiralty Board. Note on base of second page says "19 April were not orders given on this subject yesterday" followed by "ordered this day".

113. Cossons, op. cit., n.28, p.300.

114. Ibid, p.300.

115. A.W.Skempton, 'History of the Steam Dredger 1797-1830', *Transactions of the Newcomen Society*, (1975), 47, pp.97-98.

116. Jackson, op. cit., n.8, pp.102-104.

117. Skempton, op. cit., n.115, p.97.

118. ADM 1/3526, Letter of 18 April 1800 from Samuel Bentham to the Admiralty Board.

119. ADM 180/13, Progress book, page 804.

120. ADM 180/13, Progress Book, page 804.

121. Lyon, op. cit., n.16, pp.316-320.

122. P.J.G.Ransom, *The Archaeology of the Transport Revolution 1750-1850*, World's Work Limited, London, 1984, pages 75-82.

123. P.N.Thomas, *British Steam Tugs*, Warne Research Publications, London, 1984, page 12.

124. Day and McNeil op. cit., n.25, p.665.

125. Goodrich Collection, A247, Letter of 4 July 1808 from James Linaker to Simon Goodrich.

126. Goodrich Collection, A 262, Letter from James Linaker to Simon Goodrich.

127. Mary Hallett, *Portsmouth's Water Supply 1800-1860*, The Portsmouth Papers, Portsmouth, 1971, No 12, pages 5-8.

128. Morriss, op. cit., n.50, p.45.

129. *Portsmouth Dockyard Papers 1774-1783: The American War*, A calendar compiled by R.J.B.Knight, City of Portsmouth, Portsmouth, 1987, page lvi.

130. William Page, (ed), *The Victoria History of the Counties of England - Hampshire and Isle of Wight*, Institute of Historical Research, London, 1973, reprint of 1912 edition. v.V, p.388.

131. If pronounced with a hard G, the word sounds like Jetty and it may therefore be a spelling of that word.

132. ADM 1/3525, Letter of 12 Feb 1797 from Samuel Bentham to the Admiralty Board.

133. Knight, op. cit., p.129, para 91.

134. POR/D/26, Letter of 23 August 1791.

135. Brian Wright, *Firefighting Equipment*, Shire Publications Ltd., Princes Risborough, 1989, Volume 232, page 9.

136. Cossons, op. cit., n.28, pp.191-192.

137. Cossons, op. cit., n.28, p.192.

138. R.C.Riley *The Evolution of the Docks and Industrial Buildings in Portsmouth Royal Dockyard 1698-1914*, The Portsmouth Papers No 44, Portsmouth, 1985, pages 7-8.

139. Knight, op. cit., n.129, p.80, para 94, and p.79, para 89.

140. Coad, op. cit. n.1, p.167.

141. Ibid, p.48.

142. Riley, op. cit., n.138, p.21.

143. Coad, op. cit., n.1, p.238.

CHAPTER SEVEN
THE INTRODUCTION OF NEW TECHNOLOGIES INTO PORTSMOUTH DOCKYARD

7.1 Introduction of New Technologies into Portsmouth Dockyard. Chapter Two introduced the various Authorities and bodies who were ultimately responsible for approving and funding new technology in Portsmouth Dockyard whilst Chapters Three to Five considered the reasons for such introductions. Chapter Six reviewed the relevant new technologies which were potentially available and identified those which were, and were not, in fact exploited. This Chapter now looks at the individual applications of the new technologies in the Dockyard with reference to who proposed them, how they came to be approved, procured and installed and how that installation took place in relation to the Dockyard site itself, other installations within it and to the people who worked in that yard. It does this by first examining the common aspects affecting all installations before moving onto the specialist work areas along the lines followed in earlier Chapters, although in this Chapter, consideration of the steam engines, the dockyard site and the dry docks comes ahead of the familiar areas of metal and wood since the dock and steam engine investment were very much "common" considerations.

It is impossible to avoid consideration of the administrative aspects which governed so much of the process of introducing new technology into the Dockyard but discussion of them is limited, as far as is possible, to the consequences of the "inputs" to and "outputs" from the process, as they affected the advance of technology, with the detail as a whole being presented in a series of tables and diagrams.

Inevitably the pace of the introduction of new technologies varied greatly through the period 1790 - 1815. In the period up to 1800/1801 the attention of all concerned with Portsmouth Dockyard was focused on the twin imperatives of meeting the immediate needs of the fleet and in completing the major re-build of the dry dock complex which, more than anything else, was limiting the Yard's ability to match the output demanded of it. From 1803 onwards however the pace of technological innovation steadily increased until the moment when victory in the war against France appeared assured and hence the need for the fleet began to decline. At that point the funding for new applications began to dry up.

At the start of the period the Admiralty was severely limited in the selection of suitably qualified personnel to whom it could delegate the actual authority for initiating and implementing the introduction of new technology, to a relatively select and small number of technical entrepreneurs and inventors none of whom were long term naval personnel or Admiralty servants. However, as events unfolded, there was a steady growth in technical familiarity across the Navy Board's fields of responsibility until by the end of the period we see the appointment of the first de facto "Chief Engineer" of the Navy and the recognition and growth of a range of technical skills across the Dockyard area.

The installation of steam power was undoubtedly a major part of the "engine of change" throughout and by the end of the period Portsmouth dockyard had no fewer than 8 steam engines installed on site with their combined power generation having risen from 12hp in 1797 to 146hp by 1814.

Common to all considerations of new technical applications in Portsmouth Dockyard was the site itself. Paradoxically the fact that the site was surrounded on two sides by water, which made it so suitable as a Dockyard in the first place, was also the principal cause of the management not being able to take a "green field" approach to the establishment of new plant and being so constrained in how they approached each new installation. This engendered a parsimony with land allocation and a leaning to duplication of use wherever possible. The resultant technical advances therefore tended to be innovative in their installations.

After an examination of the Metal and Wood working areas the Chapter is completed with an overall view of the technical investments and advances that are discussed within it.

7.2 Administration Process for Introducing New Technology. Figure 7.1 attempts to illustrate the principal administrative steps in the process between the origination of an idea for new technology in Portsmouth dockyard through to the point at which the resultant plant was in full use.

7.2.1. Proposals & Approvals. At the "new ideas" stage there was effectively a figure of eight (illustrated in purple with the element designators being prefixed by "P") between the Admiralty Board, the Navy Board and the Dockyard with the Navy Board being at the centre of the pattern. Ideas were brought to the Navy Board either from the Dockyard or from a wide range of interested parties such as civilian entrepreneurs, engineers, serving officers or from commercial organisations involved in the maritime business - be that in terms of operating ships or in terms of supplying and fitting equipments to them.

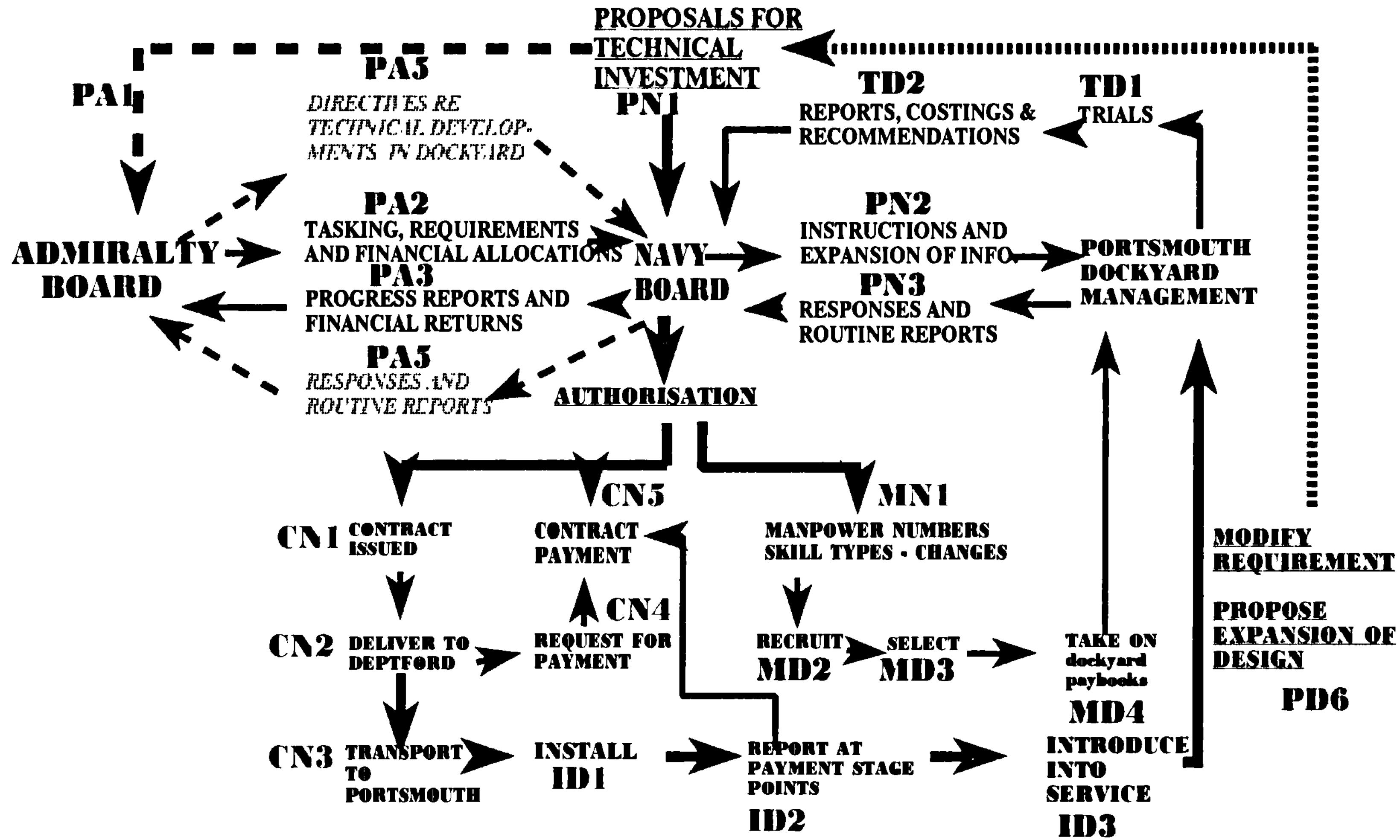


FIGURE 7.1 THE PROCESS OF APPROVAL/INTRODUCTION OF NEW TECHNOLOGY

Where the Navy Board thought an idea worthy of consideration it would be passed to the Dockyard Officers for their comments and possibly trials of the proposed process or equipments might have then been undertaken. When appropriate, plans and models were used for evaluations and to generate estimates of costs. The results of all this work were then forwarded to the Admiralty Board who made their own assessment of its value, often seeking additional information, more detailed plans or refined costs via the Navy Board, before authorising or discarding the proposal.

7.2.2. Procurement & Contracts. Shown in Green in Figure 7.1 and prefixed by "C" is the procurement and contract part of the process. Authorization, often recorded as a note on one corner of the original proposal, was then given to the Navy Board to proceed and that body issued a warrant to the Dockyard to undertake the necessary work. Much of the subsequent planning and administration fell upon the Dockyard; a site within the Yard had to be found for the new project and buildings adapted or built to house the necessary equipment before contracts or orders for equipment were placed. Subsidiary systems such as a water supply which might mean the extension of an existing system or a power supply had to be made available plus storage space for raw materials and fuel.

Contracts and orders for equipment were generally placed by the Navy Board, but both the Dockyard and the Inspector General's office were frequently delegated authority to place orders with manufacturers who were well known to them, and with whom they had had previous dealings; or in the case of the Dockyards, with established local firms who had a proven track record for providing good service.

Deliveries of equipment were made either to Deptford, which acted as a central 'clearing house' for the Navy, for onward shipment or directly to the Dockyard concerned. Equipment arriving from the west side of the country was generally sent straight to Portsmouth rather than going via Deptford. Requests to the Navy Board for payment of bills by contractors were passed to the Dockyard for scrutiny and confirmation of delivery of goods or services and that they were up to specification for their proposed tasks. Only when this confirmation was received was authorization given to pay the contractor. Even then the complete bill may not have been paid without additional and protracted exchanges of correspondence. Where large sums of money were involved, payments tended to be made by instalments[1] though these may also have been somewhat tardy.

7.2.3. Manpower - Changes and Additions. As well as the provision of facilities and equipment, suitable men had to be recruited to operate the new processes - this is shown in blue on figure 7.1 and prefixed by "M". Once suitable men had been found, the Dockyard was then authorised by Navy Board Warrant to enter them on the Dockyard paybooks.

The technologies concerned dictated the likely sources of recruitment. In the case of the Wood Mills where the Dockyard was mechanizing familiar hand skills, men could be drawn from within the Yard or from the local area, depending upon their aptitude for learning the new skills. However there was undoubtedly a problem in recruiting and training the workforce for the fresh skills that new technology was demanding. In the case of the Metal Mills, men had to be recruited from far afield due to the limited nature of metalworking in the Dockyard's catchment area. It is on record that the dockyard went as far away as Birmingham in its drive to recruit appropriate technical personnel.

Perhaps the most interesting aspect of the interface between the dockyard workforce and the new technologies is the apparent lack of any real resistance by the former to the latter. Indeed there does not appear to be a single recorded case of complaint that the new machines were taking away their livelihood, which was a not uncommon facet of the Industrial Revolution as a whole. The causes of this apparent anomaly seem to be attributable to the facts that by 1802, when the new technologies were beginning to come into service, the workforce's attention was probably focused on the inability of its pay to match the rampant inflationary prices of the most basic essentials of life. Consequently the Yard was seriously undermanned and hence there was plenty of work available for the traditional skilled men; therefore they did not feel threatened by the new technology and did not see it as a challenge to their continued employment. In fact it actually offered the prospect of advancement to those less skilled men who were willing and able to learn new skills.

7.2.4. Installation and Service. Lastly there was the installation and introduction into service stages (identified in figure 7.1 by the prefix "I" and the use of red) and this work was frequently carried out by the contractors' men working with the Dockyard workers[2] - the Millwrights whose numbers steadily built up with the passage of time.

Throughout this Chapter the prefixed codes shown in Figure 7.1, which denote the main stages in the proposal and procurement process, are used in tables for each work area which summarise the flow of submissions/requests for information between the Admiralty Board, the Navy Board and Portsmouth Dockyard. Derived from those tables are associated diagrams (Figures), which again use the prefixed codes, and also the colours, from Figure 7.1 to illustrate the timescales of the progress of introducing new technologies into their respective areas.

7.3 The Authorities in charge of New Technology. Figure 7.1.1 shows the range of organisations and people involved in exercising authority over the technical development of the Royal Dockyards. However it has to be remembered that the effectiveness of most of these depended upon the skills and knowledge of the individuals contracted or employed rather than on their position in the managerial structure. As a manager, of the highest calibre, Bentham had the ability to see what needed to be done and he had the knowledge of Government, the Navy, the new Technology and people to make it happen. Indeed, most of the proposals for alterations and additions to the Royal Dockyards, and Portsmouth in particular, in the years 1796 to 1808 came from him and this is not surprising since it was for this very purpose that he was appointed "Inspector General of Dockyards" and the office of Naval Works was set up in 1795.

7.3.1. Office of Naval Works. Chapter Two introduced this Office and Samuel Bentham (see Table 7.1.1 for brief career summary) who without doubt was the most important figure in the technical development of Portsmouth Dockyard and his appearance in that Chapter arose both as an example of the operation of the patronage system and as a precursor to his regular appearance in successive Chapters. Almost certainly Bentham owed his invitation from the Admiralty Board, in 1794, to visit the Royal dockyards[3] and report where machinery could be advantageously introduced, to activities on his behalf by his half brother Charles Abbot (later Lord Colchester) who was at that time the Speaker of the House of Commons. It seems unlikely however that the invitation would have been issued if he had not already successfully designed, and had manufactured, machinery for the prison service[4]. That opportunity he owed to his brother Jeremy[5] the utilitarian philosopher, who was then in an influential position in that service.

FIGURE 7.1.1

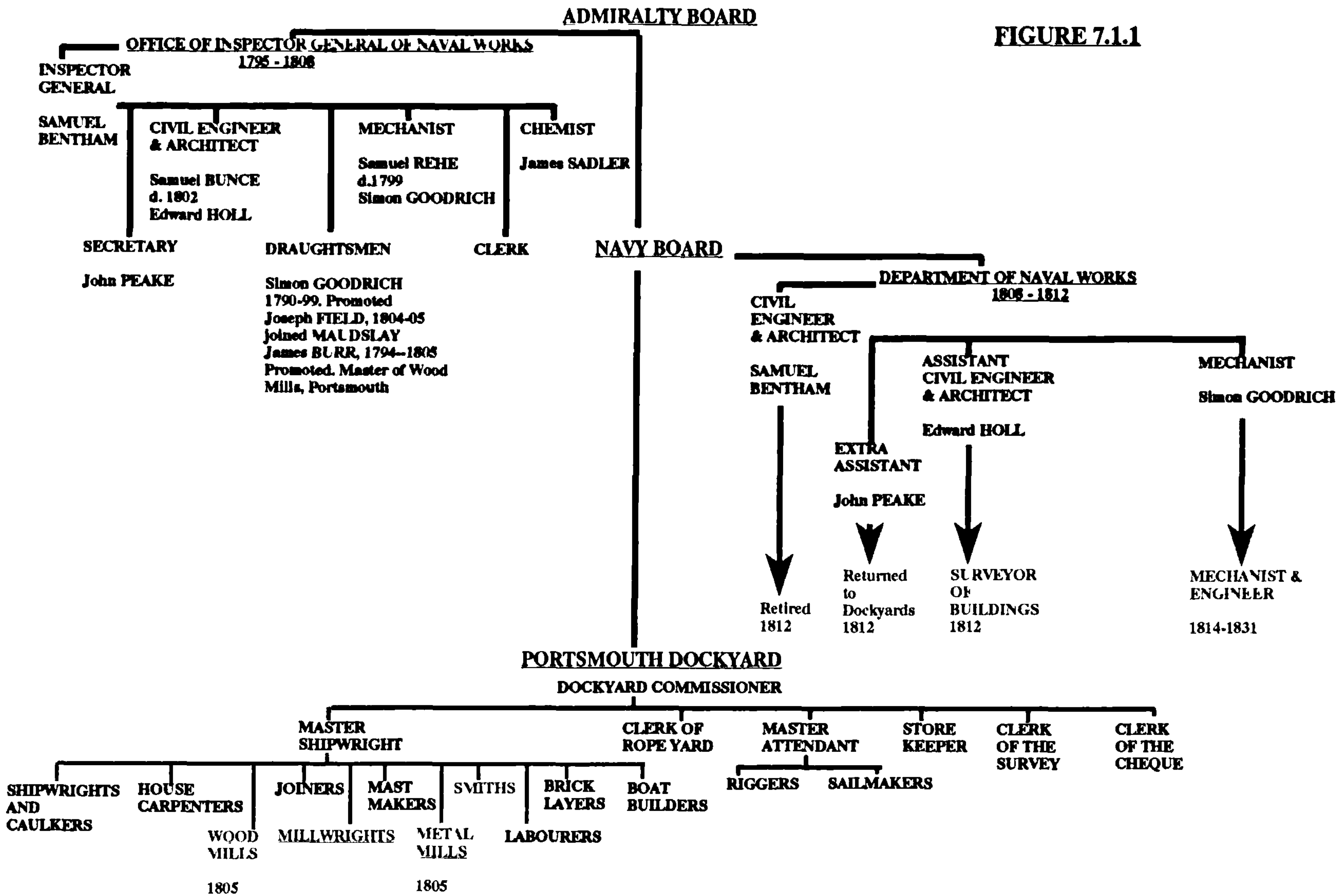

ADMIRALTY BOARD
OFFICE OF INSPECTOR GENERAL OF NAVAL WORKS
1795 - 1808
INSPECTOR GENERAL
SAMUEL BENTHAM
CIVIL ENGINEER & ARCHITECT
Samuel BUNCE
d. 1802
Edward HOLL
MECHANIST
Samuel REHE
d.1799
Simon GOODRICH
CHEMIST
James SADLER
SECRETARY
John PEAKE
DRAUGHTSMEN
Simon GOODRICH
1790-99. Promoted
Joseph FIELD, 1804-05
joined MAUDSLAY
James BURR, 1794--1808
Promoted. Master of Wood
Mills, Portsmouth
CLERK
NAVY BOARD
DEPARTMENT OF NAVAL WORKS
1808 - 1812
CIVIL ENGINEER & ARCHITECT
SAMUEL BENTHAM
Retired
1812
EXTRA ASSISTANT
John PEAKE
Returned to Dockyards
1812
ASSISTANT CIVIL ENGINEER & ARCHITECT
Edward HOLL
SURVEYOR OF BUILDINGS
1812
MECHANIST
Simon GOODRICH
MECHANIST & ENGINEER
1814-1831
PORTSMOUTH DOCKYARD
DOCKYARD COMMISSIONER
MASTER SHIPWRIGHT
SHIPWRIGHTS AND CAULKERS
HOUSE CARPENTERS
WOOD MILLS
1805
JOINERS
MILLWRIGHTS
MAST MAKERS
METAL MILLS
1805
SMITHS
BRICK LAYERS
LABOURERS
BOAT BUILDERS
CLERK OF ROPE YARD
MASTER ATTENDANT
RIGGERS
SAILMAKERS
STORE KEEPER
CLERK OF THE SURVEY
CLERK OF THE CHEQUE

TABLE 7.1.1.

NAME: Samuel Bentham	
Date of Birth	11 January 1757
Place of Birth	London
Father's Occupation	Lawyer - Jeremiah
Influential Relatives	Brother - Jeremy Bentham, utilitarian philosopher Half-brother - Charles Abbot, Lord Colchester, later Speaker of the House of Commons
Education	Westminster School,
Married	Maria Sophia
Children	Yes
EMPLOYMENT/TRAVEL RECORD	
Date(s)	*Detail*
1771 - 1778	Apprenticed to Master Shipwright at Woolwich/Chatham
1780 - 1791	In Russia, worked for Prince Potemkin, able to travel widely. Served with Dnieper Flotilla during Russian-Turkish War. Promoted Brigadier-General.
1791	Returned to UK to visit manufactories. Father died. Decided to remain in UK.
1791 - 1793	Patents for machines mainly for woodworking 26/11/1791 and 3/4/1793.
1794	Asked to visit Royal Dockyards and report on them.
April 1795	Admiralty gave approval for Office of Inspector General of Naval Works to be set up.
25 March 1796	Warrant entitling Bentham to salary of £750 per annum.
Aug 1805 - March 1808	In Russia. On return found office was to be incorporated into Navy Board.
1812	Department of Naval Works abolished. Pensioned.
1814 - 1827	Living in France with his family
1831	Died in London aged 74.

Obviously his subsequent report went well beyond what was initially envisaged but it found favour as the Admiralty Board approved Bentham's plan for an Office of Naval Works. This was set up as a part of the Admiralty Board and was intended particularly to address improvements in the construction and fitting out of ships, the buildings within the Dockyards, improvements in machinery, the tools then in use and the introduction of new machinery. Therefore, most significantly, Bentham had direct access to the Admiralty Board rather than having to present his ideas to the Navy Board first, although papers relating to the establishment of his office say " ....without taking the business in any respect out of the accustomed channels[6]."

It would be a fair observation that real progress was rarely achieved (some would say "is" rarely achieved) in "Military" matters via accustomed channels and it is equally fair to assume that Bentham did not achieve what he did by this means nor, in the process of effectively bypassing them, did he endear himself to the Navy Board members.

Planned by Bentham to have a staff of about 15, the strength of the Naval Works Office was reduced by the Admiralty Board[7] to around seven. They were Bentham as the Inspector General, John Peake his secretary, Samuel Bunce as Architect and Civil Engineer, Samuel Rehe as the Mechanist, and a Chemist - James Sadler, with the team being completed by a draughtsman and clerk. In fact, there seems to have been more than one draughtsman as Simon Goodrich and James Burr were certainly in the office at the same time. The Office was established in 1795 and functioned until 1808 when it was incorporated into the Navy Board as the Department of Naval Works being somewhat reduced in size as the post of Chemist was abolished at this point. The Department was eventually disbanded in 1812 and Bentham pensioned off but the posts of Architect and Mechanist survived as Surveyor of Buildings and Mechanist & Engineer respectively.

7.3.1.1. The Architect: His work took up a substantial part of the working regime of the Inspector General's office. As well as all the building within the Dockyards, he dealt with work for the Victualling, Sick & Hurt Boards and the Marines, and in the course of his duties travelled from Great Yarmouth on the East Coast as far as Hawlbowline Island off Southern Ireland. Given the scale of building work that took place in Portsmouth during the period it is fair to conclude that this official was regularly involved with the development of that Dockyard.

7.3.1.2. The Mechanist: was responsible for the implementation of technical projects and travelled extensively between the Dockyards and to contractors. In addition, either alone or in company with Bentham, he visited leading manufacturers of the day to keep abreast of new developments which were of interest to the Royal Dockyards. In key projects he also operated on occasions as the "on-site" manager who controlled the day to day activities of the workforce associated with bringing the equipments into service, and liaised directly with the designer and builders of equipment. It is clear from his diary that after Simon Goodrich became Mechanist, he was regularly on site in Portsmouth and in the later stages of his career, after 1814, his office was at actually in Portsmouth rather than London.

7.3.1.3. The Chemist: The post does not seem to have been particularly successful although Bentham appreciated that such skills and knowledge were necessary. It may be that James Sadler was not the right man for this post. He had started his career as a balloonist and was introduced to Bentham in 1796 by his patron William Windham who was Secretary for War but there is no evidence to suggest that he was really qualified for such work. In any event there was very quickly a high-level loss of confidence in his abilities and in 1806 he had to defend himself against charges of ineptitude. Nevertheless he had undoubted mechanical abilities and his table engine, one of the very first of its kind, worked successfully for 10 years in Portsmouth dockyard until replaced by a more powerful engine.

7.3.1.4. The Draughtsmen: several of the those who served in the office were to rise to more eminent roles. James Burr subsequently became Master of the Wood Mills and Joshua Field is better known as the partner of Henry Maudslay. Simon Goodrich, who started his career as a draughtsman in the Inspector General's office in 1796 (see Table 7.1.2), had risen by 1805 to be the Mechanist. He acted as Bentham's deputy in charge of the office whilst Bentham was away for three years in Russia. Subsequently, in 1814, he was appointed Engineer and Mechanist to the Navy Board.

NAME: Simon Goodrich	
Date of Birth	28 October 1773
Place of Birth	?Suffolk
Father's Occupation	NK - Isaac
Influential Relatives	
Education	NK
Married	Yes
Children	Yes
EMPLOYMENT/TRAVEL RECORD	
Date(s)	*Detail*
1773 - 1796	Details of education and training not known
25 December 1796	Draughtsman to Mechanist in Inspector General of Naval Works office.
25 October 1799	Appointed Mechanist on death of Samuel Rehe.
Aug 1805 - March 1808	Acted as Bentham's deputy during his absence in Russia.
25 December 1812	Department of Naval Works abolished.
Dec 1812 - April 1814	Served as Mechanist without warrant.
April 1814	Re-appointed as Engineer and Mechanist to Navy Board, resident in Portsmouth with salary of £600.
1831	Retired with a pension of £400 per annum.
1834	Moved to Lisbon in Portugal.
1847	Died in Lisbon aged 74.

7.3.2. Industrial Personnel. As important as the Naval Authorities were the technical inventors and the industrialists who were able to translate inventions into successful systems. Pre-eminent in these fields was Marc Brunel who was contracted for the extensive work he did for the Admiralty rather than being employed by them. Amongst the manufacturers of new equipments for the Dockyard, famous names which appear in the records are Henry Maudslay and Boulton & Watt but there were others less well known, for example John Lloyd a London millwright who produced equipment for the Wood Mills, the steam dredger and actually constructed Sadler's table engine.

It would be easy to place too much importance on the roles of Brunel and Maudslay in Portsmouth since, from the viewpoint of the Dockyard, they were primarily involved only with the Block Machinery project. This project came at an important moment in both their careers, as it proved to be the first big contract that either of them undertook and it set them both on the road to greater fame and success.

Clearly, in the 1790s, the levels of expertise in the fields associated with marine activities were in very short supply and only a combination of good fortune on behalf of the Admiralty and Navy Boards brought this talented team together at this important point in the Royal Navy's history. It is also important to appreciate that neither power nor money was available to alter the ability of Government Service to increase significantly the rate of attraction of such people to its cause since there was no way that a Government Department could match the financial fortunes being made in the new commercial manufacturing centres arising from the Industrial Revolution.

7.3.3. Dockyard Officers. The Dockyard Commissioner was a senior naval officer who was generally completing his career in a shore post rather than being a civilian like the remainder of the Dockyard staff. As well as being the primary link between the Dockyard Officers and the Navy Board, he acted as the focal point between the Port Admiral and thus the Fleet, and the Dockyard Officers over ships which needed immediate attention as opposed to planned refits and repairs. There were just two incumbents of this post between 1790 and 1815 and the stability they brought to the management of the Dockyard during this period of intense activity and development was important. Figure 7.1.1 shows the managerial structure immediately beneath the Dockyard Commissioner down through the

Dockyard Officers. As was seen in Chapter 5, the two largest organisations in the Dockyard were those of the Master Attendant and the Master Shipwright.

7.3.3.1.The Master Attendant, who was recruited from the ranks of experienced ships' masters, was in charge of all matters afloat in the Dockyard and the harbour. His department had charge of all the ships in Ordinary, all ship movements within Portsmouth Harbour and any related matters such as moorings, buoys and pilotage. In addition, it prepared ships for docking, docked and subsequently undocked them. Also part of the Master Attendant's department were the riggers and sailmakers - the two Dockyard crafts which did some part of their work afloat as well as ashore.

The departments of the Master Attendant and the Master Shipwright worked closely together, particularly where the activities of labourers and horse teams were concerned, as both departments needed their services and therefore were "customers" for steam power.

7.3.3.2. The Master Shipwright was the senior technical officer in the Dockyard and not only did he have the largest part of the workforce in his department but he was responsible for the design and building of new warships, as well as the surveying, repair and refitting of the existing Fleet. Concurrent with that, he was charged with inspecting the work of a range of contractors who included both those building ships in civil yards and those working on building projects within the Dockyard. This latter task fell to him since traditionally he acted as architect for new Dockyard structures.

The rapidly increasing numbers of ships in the Fleet and the expansion of dockyards and associated facilities as a result of the war, greatly increased the burden on the Master Shipwrights. Even though the task of surveying transports had been removed from them by the recreation of the Transport Board in 1794, (para 2.4.3). Their load was however lightened when the Architect in the Inspector General's Office took over much of the work involved with the structure of the Dockyard buildings.

7.3.4. The Dockyard Workforce - Lower Levels of Responsibility. The Dockyard Workforce was organized within departments by trades; the larger ones being managed by a Master Craftsman with a hierarchy of foremen, quartermen and work gangs under him. It will be recalled that the structure and strength of Portsmouth's Workforce was discussed and analysed in some detail in Chapter Five where a series of Tables and Figures showed its composition on a year by year basis, whilst Figure 7.1.2 serves to remind us of the relationship between the various sites within the Dockyard.

New departments were created for the workmen recruited to service the manpower demands of the developing technologies in which the Metal Mills encompassed the refining and rolling of Copper and Iron and the Wood Mills the mechanization of the preparation of wood. The Millwrights were something entirely new to the Dockyard and were the key men who could erect and maintain large machinery of all types. In civilian industry, they became the major trade in the shops of machine and engine makers such as Boulton and Watt or Maudslay. As a Trade, the Millwrights grew out of itinerant workmen drawn from skilled workers in both the wood and the metal areas[8]. However, by the end of the eighteenth century, millwrights had become a major trade in their own right and ultimately many of the engineering trades of the nineteenth century were derived from them.

7.4 Steam Engines - Although the numbers of steam engines within the Dockyard appeared to increase quickly, each engine was carefully chosen for its projected task. A summary of the details of the individual engines appears in Table 7.2 whilst Figure 7.2 illustrates the growth in the horsepower they collectively generated. A letter[9] from the Admiralty to the Navy Board in July 1799 shows that the initial 12hp engine to pump water and run the woodworking machinery was completed and then at work. By October of that year, Bentham was proposing a second engine, supported by the Dockyard officers as they were "....of the opinion that one will not be sufficient to answer the purpose and that it will be proper to erect another as General Bentham proposes"[10]. This was approved and a 30hp engine was duly supplied by Boulton and Watt. By 1805, the 12hp engine was no longer providing sufficient power for all the demands upon these two engines. The Wood Mills which now had block machinery as well as saws and lathes, needed the full power output of the 30hp Boulton and Watt engine during the daytime and a second 30hp engine was suggested to replace the 12hp.[11]

FIGURE 7.1.2 - PORTSMOUTH DOCKYARD 1810

1 Gate
2 Mast house
3 Saw pits
4 Offices
5 Naval Academy
6 Commissioner's house
7 Gardens
8 Lot yard
9 Rigging house
10 Sail loft and store
11 Storehouse
12 Hemp house
13 Topping house
14 Double rope house
15 Hatchelling house
16 Tarring house
17 Deal yard
18 Convertors' pound
19 Canvas painting shed
20 Dock

21 Building slip
22 Officers' houses
23 Workshops
24 Smiths' shop
25 Metal mills
26 Millwrights' shop
27 Boathouse
28 Block mills
29 Hawser house
30 Pitch house
31 Pumps
32 Mortar and engine house
33 Mould loft
34 Kiln
35 Store cabins
36 Stable
37 Timber storage area
38 Seasoning shed
39 Chapel

Buildings

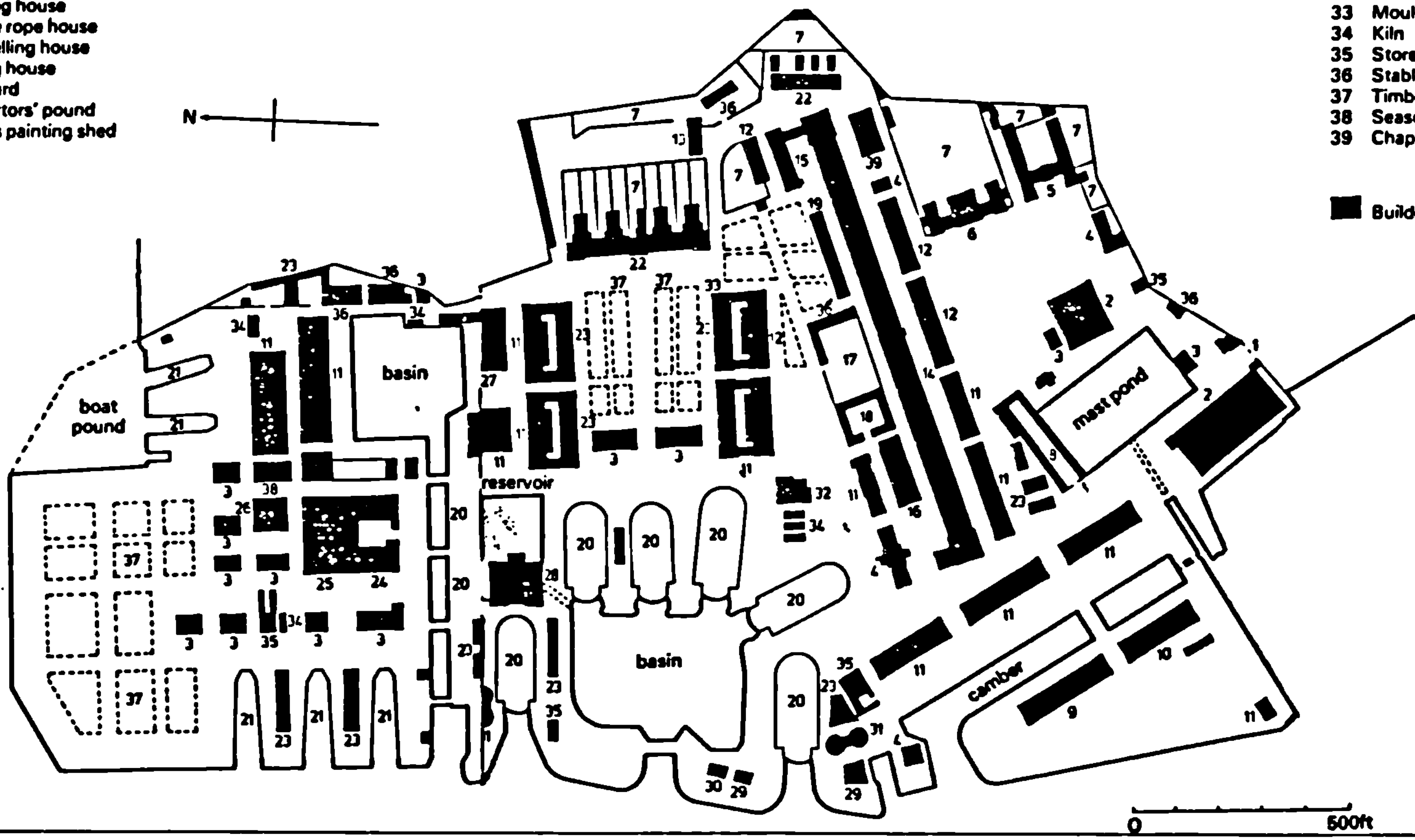


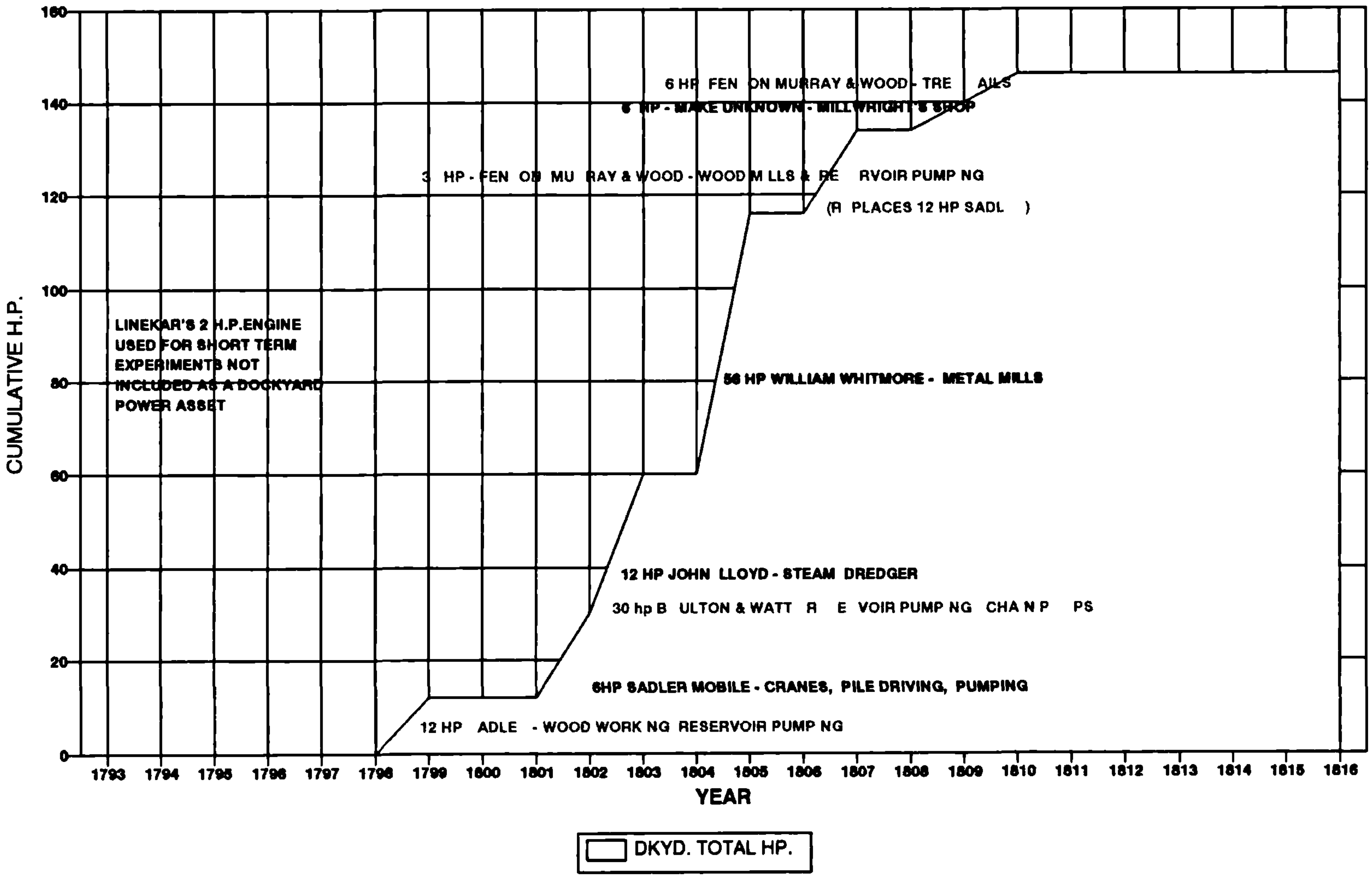
TABLE 7.2 **PORTSMOUTH DOCKYARD STEAM ENGINES**

Prop.	Sup.	I.S.D.	H.P.	Use	Designed and/or made by	Type - Boiler type	Cylinder dia. (ins. Stroke (feet) flywheel dia. (feet)	Cost	Refits and Notes
1797	1798	1799	12	Pumps, wood-working machines	Sadler/John Lloyd	Table	28/3/circa 16	£1350	In use until 1806 when replaced by 30hp engine.
1801	1802	1802	6	Cranes, pumps, pile driving	-----/John Lloyd	Moveable,table Wooden boiler	13.5/3/6		Repair to wooden boiler 5/09, Iron boiler proposed 6/09 Mounted on two horse drawn wagons
1800	1802	1803	12	Steam dredger	-----/John Lloyd	Table type Wood boiler	20/4/14	£1640	New boiler June 1809 Cost of £1640 for engine and machinery
1799	1800	1803	30	Chain pumps	Boulton & Watt	Iron Boiler	28.5/6/	£1070	Boiler repaired & new fireplace 1806, Two new Iron boilers ordered in 1808
1800	1803	1805	56	Metal Mills	William Whitmore	Beam Iron boiler	38/7/24	£1700	Two new boilers ordered August 1807. Airpump and valves relaced November 1807
1805	1806	1807	30	Pumps, wood working machines	Fenton, Murray & Wood	Table	Not known	£1845	Spare boilers ordered in 1807 after delivery
1808	1809	1810	6	Metal Mills Millwrights	MAKE UNKNOWN.	Type Not known	c.12/ - /c.3.5	£380??	Later moved to New Shop
1809	1810	1814	6	Wood Mills Treenails (Eventually)	Fenton, Murray & Wood	Type Not known	c.20/ - /10	N.K.	Original reason for purchase not clear.
N.K.	1810	N.K.	2	Experiments	Not Known	Type Not Known	Not known	N.K.	Used by Linaker for experimental propulsion trials May have been used short term by the Millwright Smiths during their re-location. (NOT included in Figure 7.2)

225a.

FIGURE 7.2

AVAILABILITY OF STEAM POWER IN PORTSMOUTH DOCKYARD



On this occasion, Whitmores and Fenton, Murray and Wood of Leeds both bid for the work but, on Goodrich's advice, the Navy Board ordered a 30hp table engine from Fenton, Murray and Wood on 19 December 1805[12]. Despite their bid at £1845[13] being more expensive than Whitmores[14] at £1656. However, Goodrich felt, in the light of experience with the engine in the Metal Mills, that the Whitmore company's workmanship was not of the standard required[15]. The Fenton engine was delivered to Portsmouth during the late summer of 1806[16] and was erected by August 1807, when the bill of £157/14/6d for travelling and expenses for Fenton's engineer was paid[17].

The largest capacity engine was that for the Metal Mills which was 56hp, and Whitmore of Birmingham included the engine and one boiler in his estimate of 1803[18] to supply the necessary equipment to run the rolling mills. In 1807, when Goodrich was proposing that the Metal Mills could make copper bolts as well as sheathing, he conducted trials to "....see if there is sufficient power to keep sheathing rolls going at the usual rate at the same time"[19]. The trials proved the point as the scheme was successfully put into practice[20], interestingly, despite Goodrich's earlier adverse opinion on its workmanship, this engine successfully remained in service throughout the period.

Following the introduction of these large engines, Portsmouth's subsequent acquisition of new steam engines, and associated plant, was very much more modest and, within the period, it was limited to just two, possibly three, small engines each of which was less than 10 horse power. Two drawings for 6hp engines survive, one of which is marked "....for the new Millwrights shop" and is thought to date from 1809[21]. This accords with the Navy Board approval in 1808 for a steam engine, lathes, drilling apparatus etc. for the Millwrights[22]. Later, in 1813, when the Dockyard was reporting on progress with a new building, they said that "The seasoning shed at the west end of the Boathouses has been removed and the building erected for a Smiths shop for the Millwrights with six forges, three lathes have been fixed in the said shop removed from over the Coal Cellar and one is left there for the use of the Millwrights. The boring machine is in hand making. The small engine is complete and fixed"[23].

A second drawing, dated 18 April 1809[24], shows a 6hp engine of a very different design which was a small beam engine on an 'A' frame and this appears to have been obtained from Fenton, Murray and Wood in 1810[25]. Sadly, Goodrich's diaries for November 1808 to April 1809 are missing and there is no other remaining evidence of what the rationale for its acquisition was but in 1813 Burr was suggesting a power source for Beale's treenail machine as

"....present machine fully employed by Block Mills which are short of space, suggest small 6hp engine in a very forward state and needing a task..."[26]. This suggests either that the 1809 drawing took some years to turn into a real engine on site or that that engine was first used for some purpose we can no longer identify and became available for re-assignment around 1813. Of these two possibilities, the former seems to be just the more likely.

The last requirement for an additional engine at Portsmouth in the period is suggested in February 1814 by a sketch plan which was sent to the Navy Board "....to show where 6hp steam engine for tarring yarns could be erected"[27] and in August 1814, Goodrich recorded in his Journal that he had been taking measurements for the "....chimney for engine at the Tarring House"[28]. However there is no further recorded progress on that project in the period. Indeed it would have been surprising if, at the end of the war, an engine had been ordered, built, installed and set to work in less than sixteen months.

On balance it seems fair to say that the earlier and larger horsepower engines certainly were bought for specific and clearly detailed roles and even the later and smaller ones were only procured, after analysis of the financial benefits, for continuous factory type work which would have been barely possible without this new power source.

The one notable exception to this apparent policy was "...The Moveable Steam Engine equal in power to the incessant exertion of six horses or of thirty men and applicable to the unloading of vessels, to the driving of Piles, to the pumping of Water, and to various laborious Operations"[29]. The engine and machinery, shown in Figure 7.2.1, were made by John Lloyd and were brought into use in 1802[30] mounted on two wagons which could be moved to any work site by Horses. One wagon was for the boiler and the other for the engine itself, flywheel and windlass. It was designed to provide either linear or rotary motion with the former being used for pumping or pile driving and the latter being needed to power a windlass.

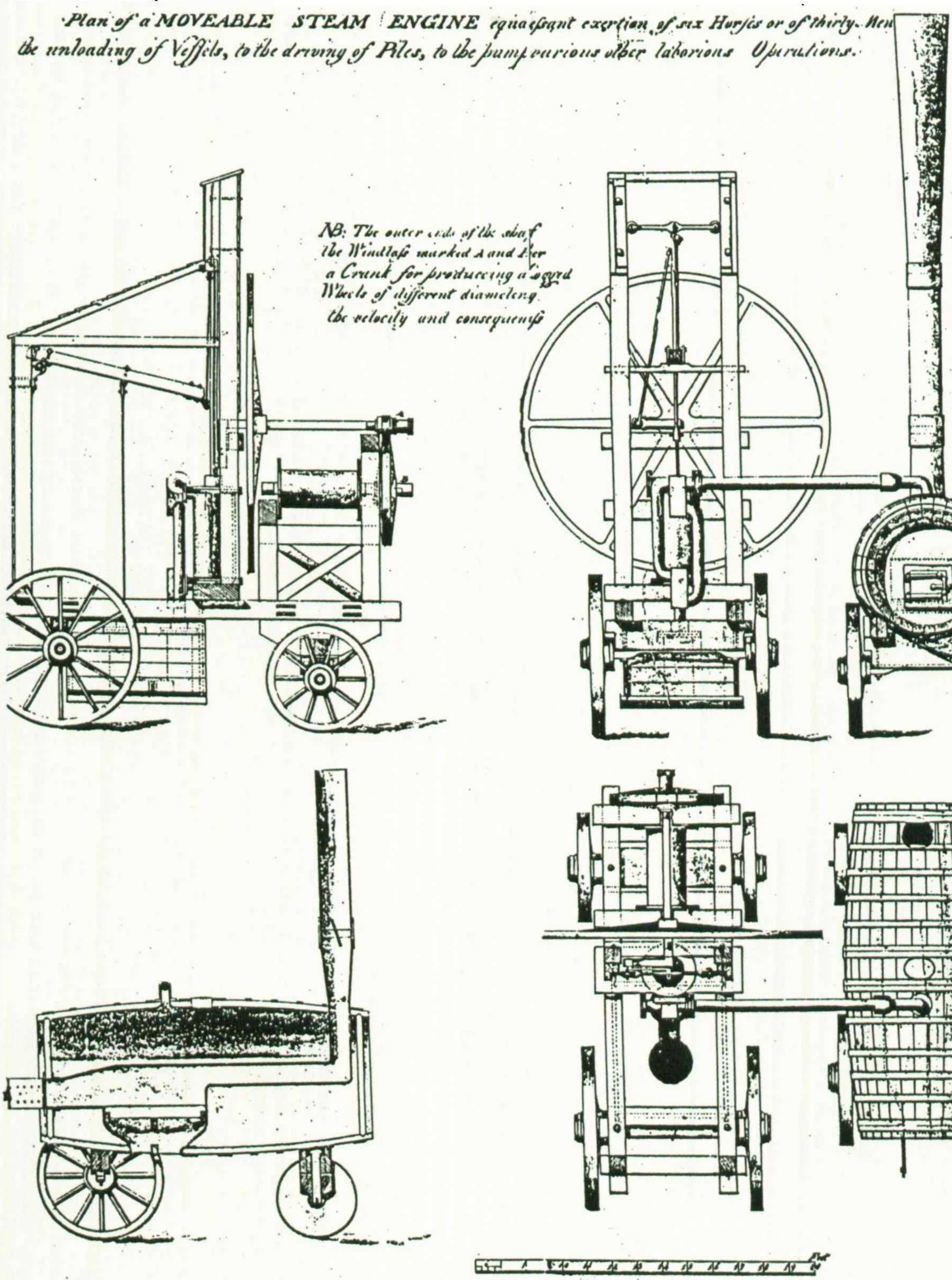
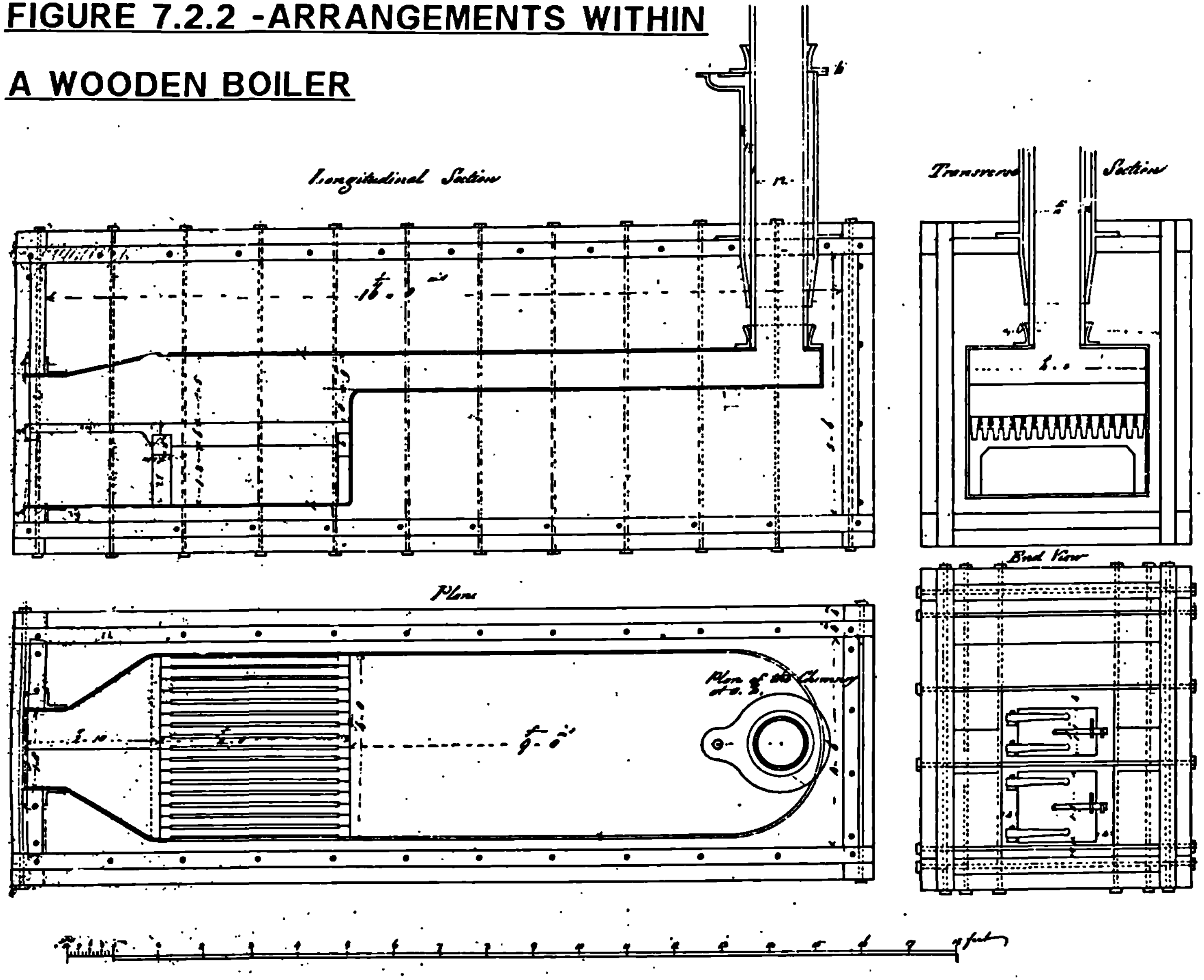


FIGURE 7.2.1 - MOVEABLE STEAM ENGINE

A most unusual feature of it, which makes it historically very interesting, is that the boiler was made from a wooden water cask, with the firebox and tube fitted within it. In general, boilers fitted to British-built static steam engines were made of iron in a variety of shapes, which were supported on, or within, a brick structure encompassing the fire and the airways to the chimney. Obviously this was not feasible for a mobile engine and a different solution to the problem was needed. This is illustrated by two drawings of 1804[31] of designs proposed for replacement for rectangular wooden boilers for both the Dredger and the Moveable steam engine (Figure 7.2.2). The fire was contained within a firebox which itself was totally enclosed within the wooden boiler cask in which the water was heated. To improve the efficiency of this process the single airway, or flue, from the firebox, a feature of the original boilers for these engines, was replaced by a series of separate tubes which only came together into a larger single flue immediately prior to exiting from the wooden cask. Thus the hot metal surface area in contact with the water was considerably increased, a similar design appears on a drawing of about 1806 which is titled "Design by Simon Goodrich for Wooden Boiler in lieu of the Cask". It appears that the Moveable steam engine boiler, at least, was not replaced in 1804 and a wooden boiler was still in use in 1809 when Goodrich was corresponding with James Linaker the Master Millwright about repairs to it[32]. This led to the suggestion of replacing it with a wrought iron case[33]. The boiler of the steam dredger was definitely replaced in 1806 as Goodrich records that he was "....on board the Ballast Engine to see the new boiler which answers very well..."[34]; unfortunately he does not say what this one was made of.

The two 30hp and the 56hp engines were initially equipped with a single boiler each but in 1807, a contract for their replacements show that the engines were then fitted with two boilers[35]. One boiler would have been working and the other being cleaned or at standby. The original boilers were made of iron and so were the replacements. At the same time, Goodrich did persuade the Navy Board to sanction the purchase of at least one copper boiler. He believed that although the initial purchase of this type was more expensive than an iron one, potentially it offered better serviceability which would have more than offset the difference in purchase price.

FIGURE 7.2.2 -ARRANGEMENTS WITHIN A WOODEN BOILER



7.5 Portsmouth Dockyard Site. As can be seen from Figure 7.1.2 the Dockyard, which embraced some 84 acres, was laid out with the Dry Docks complex at its heart. Given the nature of the site, the only practical option for acquiring more land was to reclaim it from the harbour and hence the existing site had to be used to best advantage. In fact a small piece of land was reclaimed in the 1790's and mainly used for seasoning timber, but the next big reclamation did not take place until the 1840's. Thus, to make space for new installations, old buildings had to be adapted or taken down and rebuilt elsewhere. Indeed several of the covered timber stowages and sawpits disappeared during the enlargements to the metalworking facilities. Another method of gaining extra space was used in 1812, when the Dockyard removed the roof of the Rigging House and added a storey[36], thereby gaining more space without enlarging the site used.

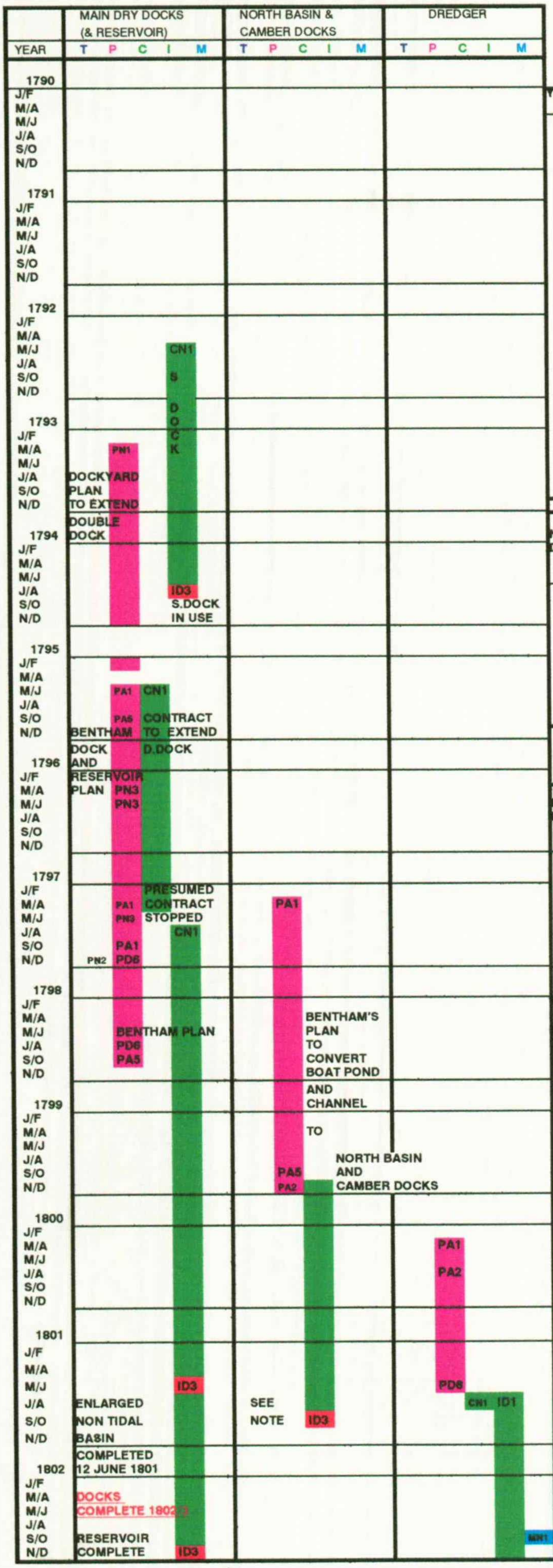
7.5.1. Dry Docks. Table 7.3 summarises the key events in the development of the Dockyard Complex and is supported by Figure 7.3 which shows diagrammatically how the development progressed. Figure 7.3.1 illustrates the layout of the complex before and after improvement. During the early 1790's, the Dockyard put in train plans for work on the Dry Docks and contracts were placed with Parlby's, a local firm, on 2 January 1792 for a new South Dock (No.1 as shown in Figure 7.3.1) and on 27 January 1795 to enlarge the Double Dock so that it could take two 74 gun Third Rates[37] rather than two frigates[38]. In April 1793, the Dockyard officers reported to the Navy Board that the South Dock should be completed by midsummer of 1794[39]. However, despite the issue of the contract for the Double Dock, the work actually never started since before it could do so the Admiralty Board had in front of it Bentham's plan (he was appointed Inspector General in April 1795) to replace the Double Dock by two single docks (Nos.2 and 3) opening into an enlarged Non-Tidal Basin. Discussion of this plan continued throughout 1796 and into 1797 when a warrant was finally issued to carry out the work on the Basin and new docks on 30 August 1797[40].

TABLE - 7.3

NOTE ORGANISATIONS - AB - Admiralty Board, NB - Navy Board, IG - Inspector General of Dockyards. SB- Bentham, SG - Goodrich, MB - Brunel, PD Portsmouth Dockyard Officers

DRY DOCK COMPLEX

CROSS REFERENCE TO FIGURE 7.1	DATE DAY/MNTH	DATE YEAR	FROM (ORG.)	TO (ORG.)	REFERENCE	SUBJECT MATTER	REMARKS
CN1	22-Jun	1792	PD	NB	POR/D/26	Contract for New South Dock placed with Parlby's	Information in letter of 18 March 1796
PN1	12-Apr	1793	PD	NB	POR/D/26	Double Dock needed	South Dock due to complete by Midsummer 1794
PA1	29-May	1795	SB	AB	ADM/Q/3320	Bentham"s plan for new docks at Portsmouth	AB-NB 2 June - stop work on double dock
CN1	27-Jun	1795	PD	NB	POR/D/26	Contract to enlarge Double Dock placed with Parlby's	Information in letter of 18 March 1796
PA5	10-Oct	1795	AB	NB	ADM/Q/3320	Confirmation of order to carry out Bentham's plan	
PA1	03-Mar	1796	PD	NB	POR/D/27	Alterations to Reservoir etc.	Part of Bentham's plan
	18-Mar	1796	PD	NB	POR/D/27	Navy Board warrants of 1 Jan & 8 March for Docks	Are certificates to be granted to Parlby & Rankin
PN3	07-Apr	1796	PD	NB	POR/D/27	Comments on Dock alterations	
PN3	18-May	1796	PD	NB	POR/D/27	Letter about alterations	
PN3	26-May	1796	PD	NB	POR/D/27	Further letter about alterations	
	17-Dec	1796	PD	NB	POR/D/27	Articles supplied by Collins and Broughton recieved	Parts for new South Dock pumps
	20-Feb	1797	PD	NB	POR/D/27	Twenty spare pump piston rods recieved.	From Collins and Broughton
PA1	04-Apr	1797	IGO	AB	ADM 1/3525	Bentham's plans to alter Docks	
PA1	08-Apr	1797	IGO	AB	ADM 1/3525	Proposal to convert Boat Canal to Long Dock	Estimated cost of £6000, to take 3 to 4 months
	13-Apr	1797	PD	NB	POR/D/27	Prices for Parlby's work on new Basin gates	
PN3	11-May	1797	PD	NB	POR/D/27	Request for plans because of scale of work	Navy Board Warrant of 6 May
	10-Jul	1797	PD	NB	POR/D/27	Plan for enlarged Basin recieved	
CN1	31-Aug	1797	PD	NB	POR/D/27	To carry out work on Docks and Basin	Navy Board Warrant of 30th August
PD6	21-Dec	1797	IGO	AB	ADM 1/3525	Proposal for steam driven pumps for two new Docks	Estimated cost of Pumps £550
	05-Apr	1798	SB	C. Abbot	ADM 1/3525	Objections to current plans for Naval Works	Bentham's alternative proposals
PD6	04-Aug	1798	IGO	AB	ADM 1/3525	Proposed changes to Basin entrance	Inverted arch of masonry, caisson
PA5	10-Sep	1798	IGO	AB	ADM 1/3525	Detail for Basin entrance	AB to NB, 10 Sept - to carry out plan
PA5	16-Sep	1799	IGO	AB	ADM 1/3525	Use of Boat Canal as Long Dock	Bentham's comments on Dockyard Officers opinions
	21-Sep	1799	IGO	AB	ADM 1/3525	Reply to letter of 30 Aug 1798 about inverted arch	AB to NB 25 Sept - Order to carry out plan
	24-Sep	1799	IGO	AB	ADM 1/3525	Reply to letter of 16 Sept 1799 re Boat Canal	Caisson to replace dock gates
PA1	25-Sep	1799	IGO	AB	ADM 1/3525	Plan to fill in Resrvoir with two floors over water	Storage for inflammables
	26-Sep	1799	IGO	AB	ADM 1/3525	Reply to 7 Sept about Estimates from Dockyard	Add £10000 to Estimates for Boat Pond alterations
	29-Oct	1799	IGO	AB	ADM 1/3525	Steam engine and single pumping apparatus erected	Been working for about seven months
PA2	05-Nov	1799	AB	NB	ADM/Q/3320	Proceed with North Basin and Camber Docks	To use Parlby's as Dkyd labour fully employed
PN2	28-Nov	1799	NB	PD	ADM/Q/3320	Opinion of Dockyard on Reservoir plan required	Ground space useful but storage not necessary
ID3	12-Jun	1801				First Ship into enlarged Non Tidal Basin	Inscription on entrance wall (R C.Riley page 12)
PA5	14-Apr	1802	AB	NB	ADM/Q/3321	Reservoir ready for buildings, estimated cost £8827	To be erected without further delay
	12-Oct	1802	PD	NB	POR/D/27	Arrangements for putting Seppings apparatus into dock	
ID3	15-Dec	1802	PD	IGO	ADM 106/2539	Dockyard reported work on Reservoir complete	Building being erected on recovered ground
	02-Jul	1811	PD	NB	POR/D/29	Need to take Basin entrance Caisson into dock for repairs	Copper sheathing and caulking to be done
	19-Jun	1812	PD	NB	POR/D/29	Need to repair Inner Boat Canal Caisson	Outer caisson moved in and inner one docked



FROM TABLE 4.3

YEAR	DOCK DAYS USED/YEAR
1790	1596
1791	1548
1792	1683
1793	1664
1794	1020
1795	1169
1796	973
1797	1177
1798	1537
1799	1349
1800	1399
1801	1400
1802	1315
1803	1878
1804	2095
1805	2021
1806	2736
1807	2261
1808	1958
1809	2522
1810	2373
1811	2411
1812	2339
1813	2486
1814	2972
1815	2693
1816	614

NO. OF DOCKS	MAX. (364) DOCK DAYS PER YEAR AVAILABLE
1	364
2	728
3	1092
4	1456
5	1820
6	2184
7	2548
8	2912
9	3276

NO. OF DOCKS	90% OF MAX DOCK DAYS PER YEAR AVAILABLE
1	328
2	655
3	983
4	1310
5	1638
6	1966
7	2293
8	2621
9	2948

UP TO 10% PROBABLY NEEDED FOR DOCK MAINTENANCE & RE-SITING KEEL BLOCKS ETC.

NOTE: BASED ON UNSUPPORTED CONTEMPORARY SOURCE

APRIL 1802 - RESERVOIR READY TO BE BUILT ON

FIGURE 7.3

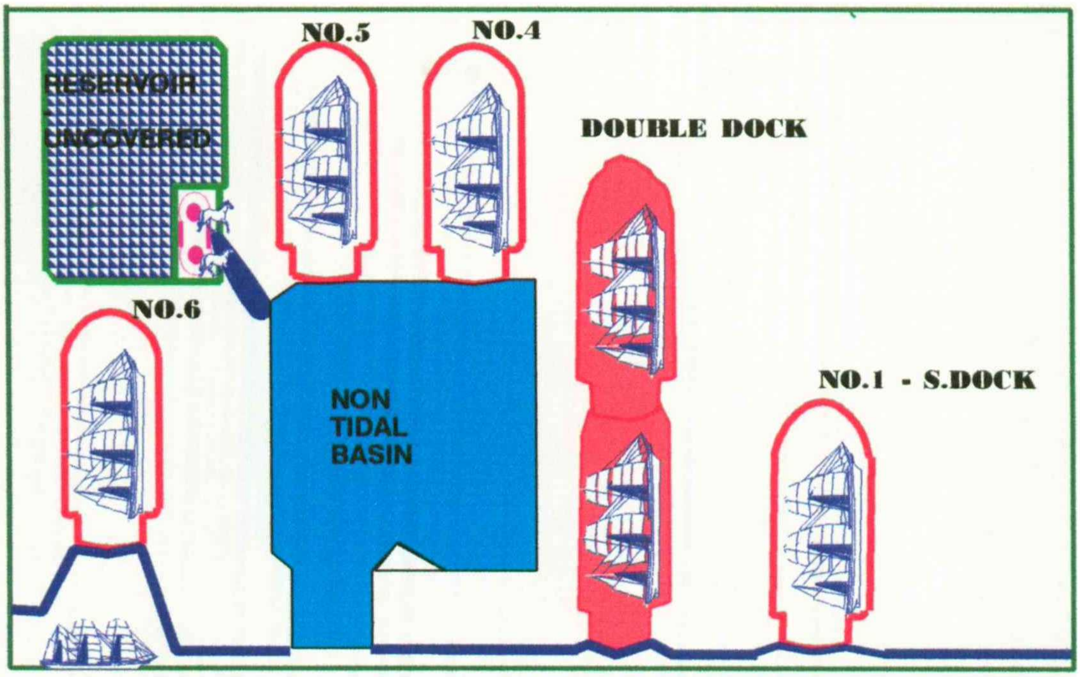
TABLE - 7.3 CONTINUED

NOTE ORGANISATIONS - AB - Admiralty Board, NB - Navy Board, IG - Inspector General of Dockyards SB- Bentham, SG - Goodrich, MB - Brunel, PD Portsmouth Dockyard Officers

STEAM POWERED DREDGER

CROSS REFERENCE TO FIGURE 7.1	DATE DAY/MONTH	YEAR	FROM (ORG.)	TO (ORG.)	REFERENCE	SUBJECT MATTER	REMARKS
PA1	12-Apr	1800	IGO	AB	ADM 1/3526	Proposal for Dredger with steam operated machinery	Admiralty note of 22 April requesting drawings
	13-May	1800	IGO	AB	ADM 1/3526	Plans for Dredger and mud barges	Info in Missing letter list of 2 April 1801
	20-May	1800	IGO	AB	ADM 1/3526	Estimates for Dredger and mud barges	Info in Missing letter list of 2 April 1801
PA2	25-Jul	1800	AB	NB	ADM/Q/3320	Request to Navy Board for report on Dredger proposal	AB note about steam engine at Deptford
	26-Jul	1800	NB	AB	ADM/Q/3320	Letters about suitable steam engine	Returned to Deptford from trials on Ambi-Navigator
	05-Oct	1800	IGO	AB	ADM 1/3526	Proposed steam engine not suitable but put in store	AB note of 18 Oct - Navy Board to proceed with proposal
PD6	22-Jun	1801	NB	PD	ADM/Q/3321	Vessel about to be taken in hand - revised plan 1/12/1800	Give orders to Portsmouth Officers
CN1	-July	1801			ADM 180/13	Keel of Dredger laid, Portsmouth Dockyard	
	16-May	1802	IGO	AB	ADM 140/499	Drawing of dredging machinery	Showing amendments to original design ??
	14-Oct	1802	PD	NB	POR/D/27	Vessel ready for launching	Details of crew etc needed
MN1	18-Oct	1802	NB	IGO	ADM 106/2539	Confirmation of readiness for launching	Bentham asked for details of manning
	22-Oct	1802	IGO	AB	ADM/Q/3321	Master plus 6 - 2 scavelmen + 4 others	Foreman of Millwrights will attend machinery trials
MD3	26-Oct	1802	AB	NB	ADM/Q/3321	Permission to man as requested	P'mth Dkyd Commissioner to be informed
	-Nov	1802			ADM 180/13	Dredger launched at Portsmouth	Hull cost £1074, workmanship £611, Total £1685
	06-Mar	1803	NB	IGO	ADM 106/2539	Lloyd's bill for machinery for scrutiny	
ID3	04-Jul	1803	AB	NB	ADM/Q/3322	Bentham's letter of 28 May about Dredger trials	Can raise 2 tons of soil per minute
PD6	19-Jul	1803	AB	NB	ADM/Q/3322	Bentham's proposes another mud barge for Portsmouth	Admiralty Board approval given
ID3	13-Jun	1806	SG		Goodrich B14	New boiler fitted	Completed and seen working by SG
CN1	18-Nov	1806	NB	IGO	ADM 106/2539	Lloyd to provide wrought iron chain for Dredger	Present cast iron chain has broken
	12-Mar	1807	SG		Goodrich B17	Estimated costs of removing dredged mud	`15d or 18d per ton
CN4	29-May	1807	NB	IGO	ADM 106/2539	Lloyd's bill for wrought iron chain for scrutiny	Has it been supplied and is it suitable
	01-May	1815	PD	NB	POR/D/30	Death of Master of Steam Dredger	Recommend mate of Well Boat for promotion

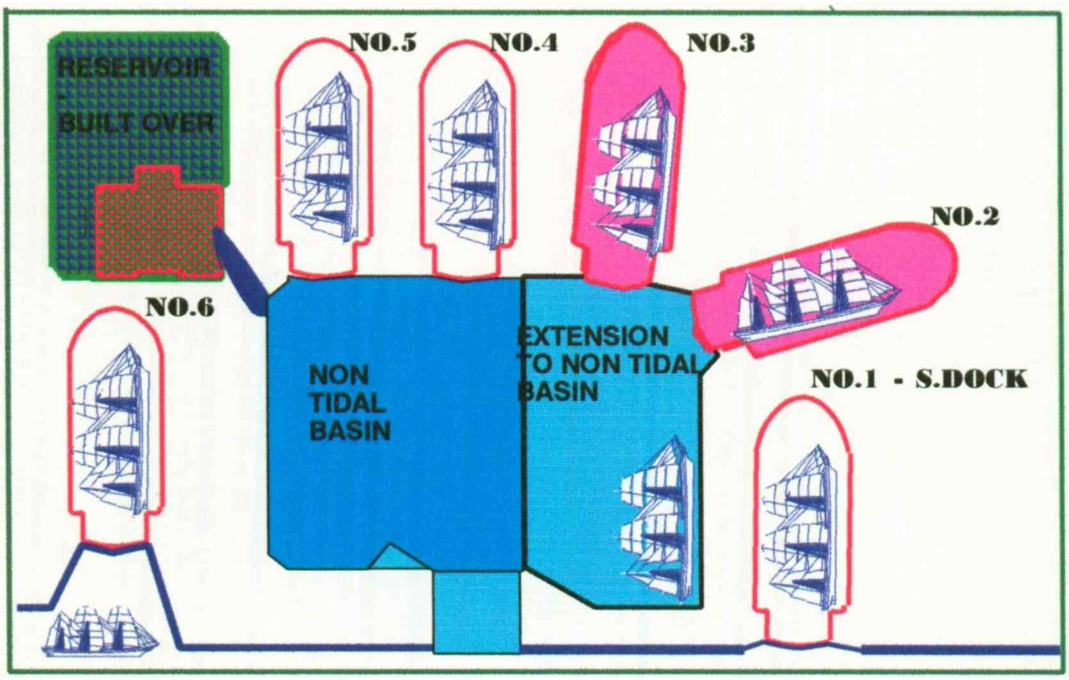
FIGURE 7.3.1



BEFORE IMPROVEMENTS

NON TIDAL BASIN & DRY DOCK COMPLEX

AFTER IMPROVEMENTS

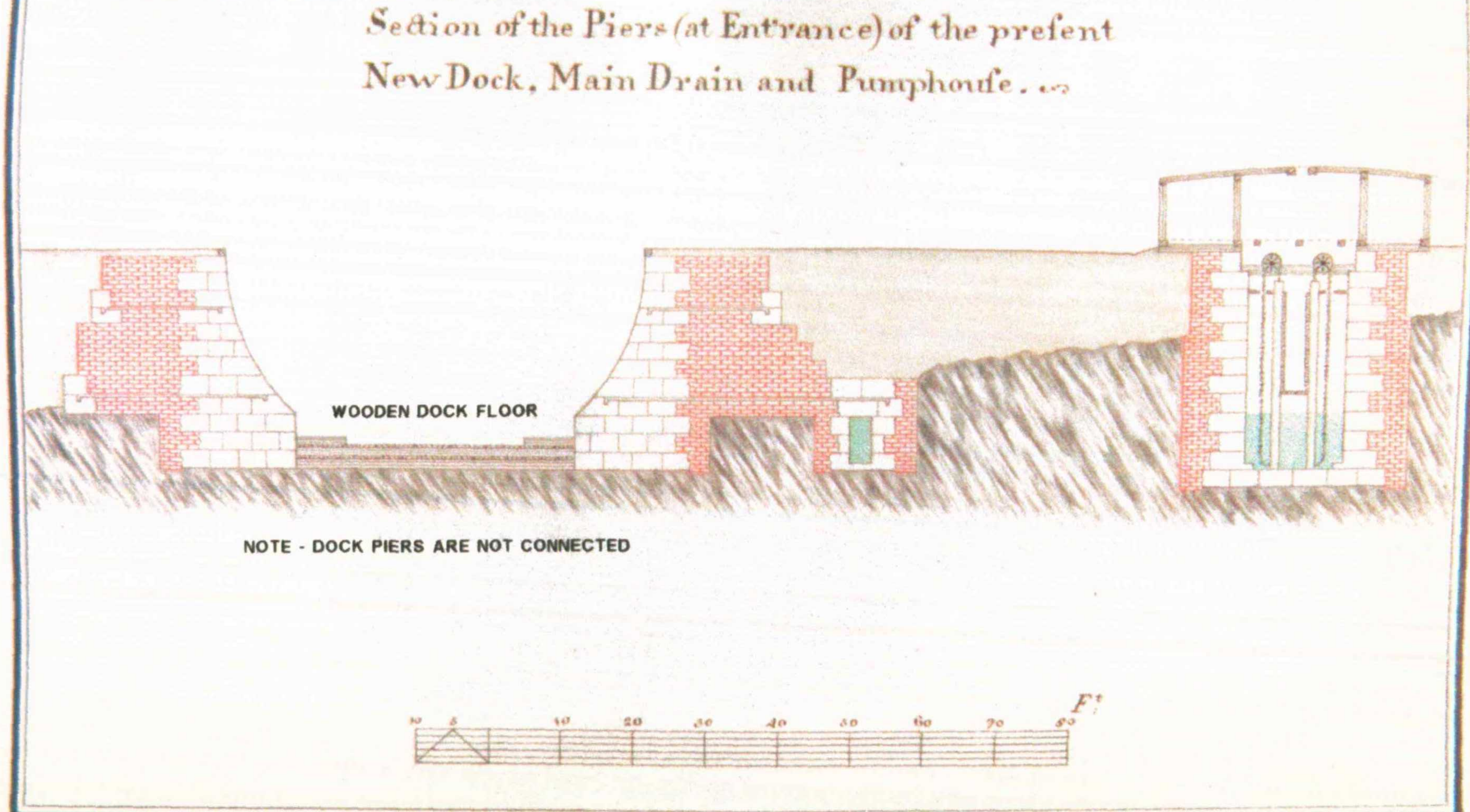


What the original Dockyard plan was trying to achieve was an increase in dry dock capacity but Bentham's plans were also trying to maximise the utilisation of the facilities and thus achieve the best possible turn-round of ships being repaired. Four single docks and one double dock provided space for six ships simultaneously, but there were problems in that two of the four single docks (Nos 1 and 6) opened into the harbour. Consequently, even though water in the dock could be removed or returned by pumps, ships could only leave the dock when there was sufficient water in the harbour, ie at high tide. Against this a Non-Tidal Basin could maintain a constant depth of water, so that once the dry dock had been flooded (water pumped into it) ships could be taken out or put in regardless of the state of the tide in the harbour. Furthermore, ships in a non-tidal basin could be worked on from shoreside without the need constantly to alter gangways, lifting devices and securing ropes to match the changing position of the ship relative to the shore edifices. Unfortunately the double dock also opened into the harbour and had the added disadvantage that as the ships were berthed one behind the other, the one at the head of the dock could only be taken out when the ship behind her was completed. Bentham's plan overcame this problem and connected 4 dry docks (Nos 2, 3, 4 & 5) to both the Non-Tidal basin and the Reservoir. The first ship to enter the enlarged Non-Tidal Basin was the First Rate, Britannia, in June 1801.

Traditionally, dry docks were built with wooden floors (Figure 7.3.2) which required very regular maintenance by shipwrights and house carpenters; the exception at Portsmouth was No 5 dock which had been built of stone in 1689. The two new docks were built with stone floors and this appears to have been a successful innovation because the wooden floors of the other docks were slowly replaced.

Measurements on a map of 1858[41] show that the South Dock and the two new single docks ,which were completed in 1802 and 1803, were both longer and the entrance sill was deeper than the earlier docks. These features enabled these docks to take the late eighteenth and early nineteenth century built warships which, type for type, were larger in all respects than those built in the 1760's and 1770's.

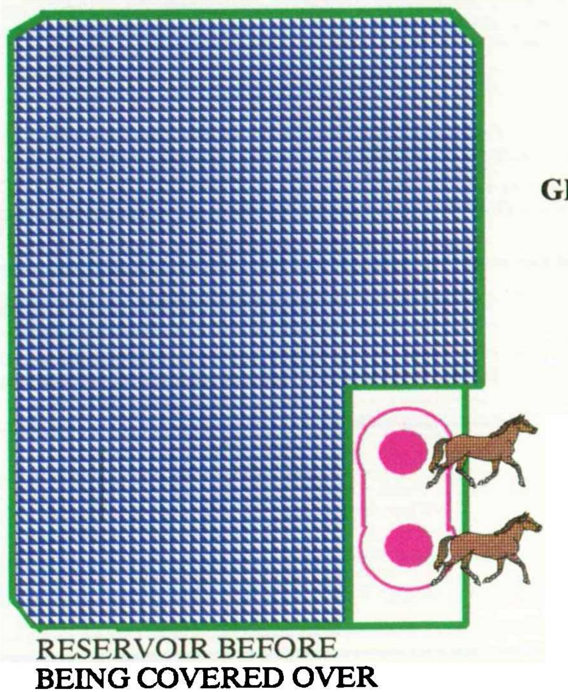
FIGURE 7.3.2

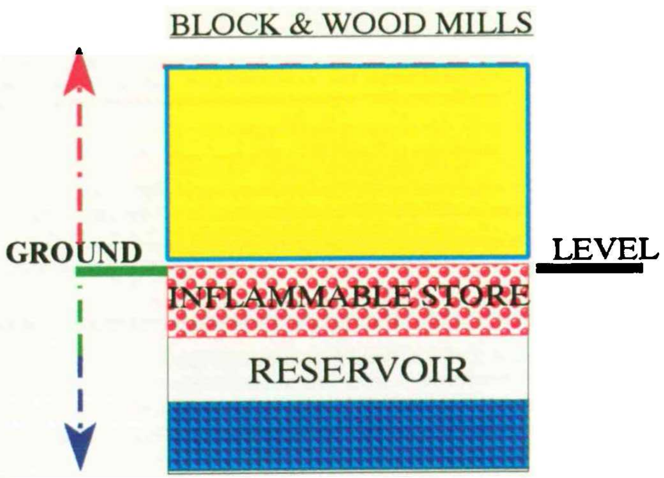

Section of the Piers (at Entrance) of the present
New Dock, Main Drain and Pumphouse.
WOODEN DOCK FLOOR
NOTE - DOCK PIERS ARE NOT CONNECTED
10
5
10
20
30
40
50
60
70
80
Ft

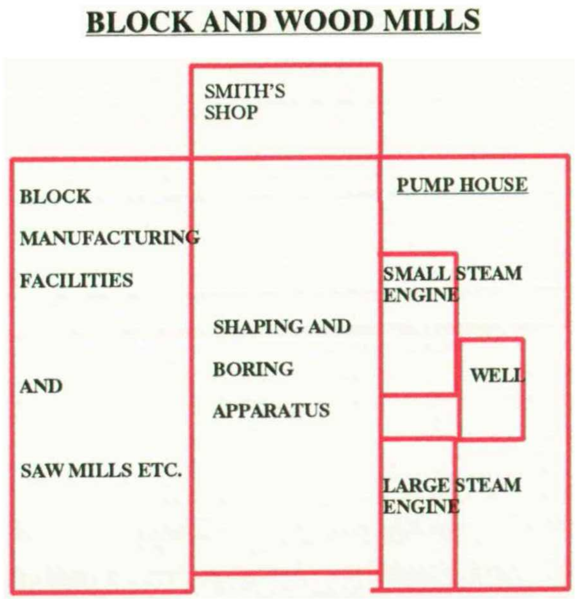
7.5.2. The Reservoir. The other far-reaching scheme to retrieve space and increase dock utilisation was the plan to cover over the Reservoir used to receive and hold the water drained down from the Dry Docks. It is possible that this concept was first put forward in around 1793 by Samuel Wyatt[42] but it was not proceeded with. However Bentham's plan was considerably more ambitious in that it also aimed to exploit the space within the Reservoir whose area was about 35,000 square feet[43] with, at that time, only eight of its thirty foot depth being exploited. By means of brick arches supported on masonry piers, a single floor building was put into the Reservoir above the stored water at an estimated cost of £16,000[44]. The floor of this building, being well above water level, but equally well below ground level, was to be used to store highly inflammable items such pitch, tallow, tow and rosin[45] rather than having them spread around the Dockyard creating fire risks. Furthermore, as the ceiling of this building was at ground level it created an area for further new building above it. The structure of the Reservoir and this building is illustrated by Figure 7.3.3.

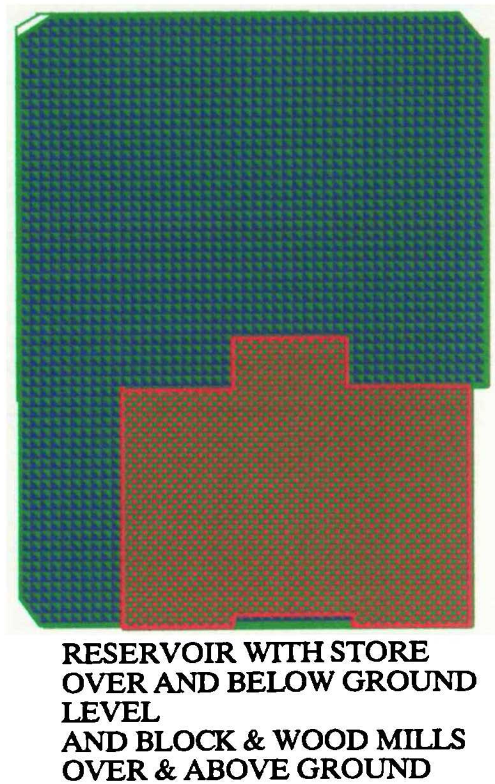
Perhaps understandably the Dockyard officers were initially critical of the range of new proposals emanating from Bentham and they had doubts over the merits of the Reservoir scheme especially as they were concerned over the need to ventilate the storage area to prevent damp from the water getting into the stores. Bentham's solution was to add passages to and from the engine pumphouse, thereby creating a warm airflow through the system[46]. In the event, the work on the Reservoir was accomplished by December 1802, when the Dockyard officers informed Bentham's office that a building on part of the Reservoir space would be completed in the spring of 1803[47]

7.5.3. Dock Pump House. An equally effective approach was adopted when the existing pumphouse beside the Reservoir was to be altered to take a steam engine which would drive chain pumps instead of the horse-gin. Bentham suggested that an adjoining building could house the sawing machinery which could share the steam engine's power with the pumps[48]. This would run the steam engine to best advantage, working the sawing machinery by day and when needed, pumping the water for the docks at night. This is again illustrated by Figure 7.3.3.









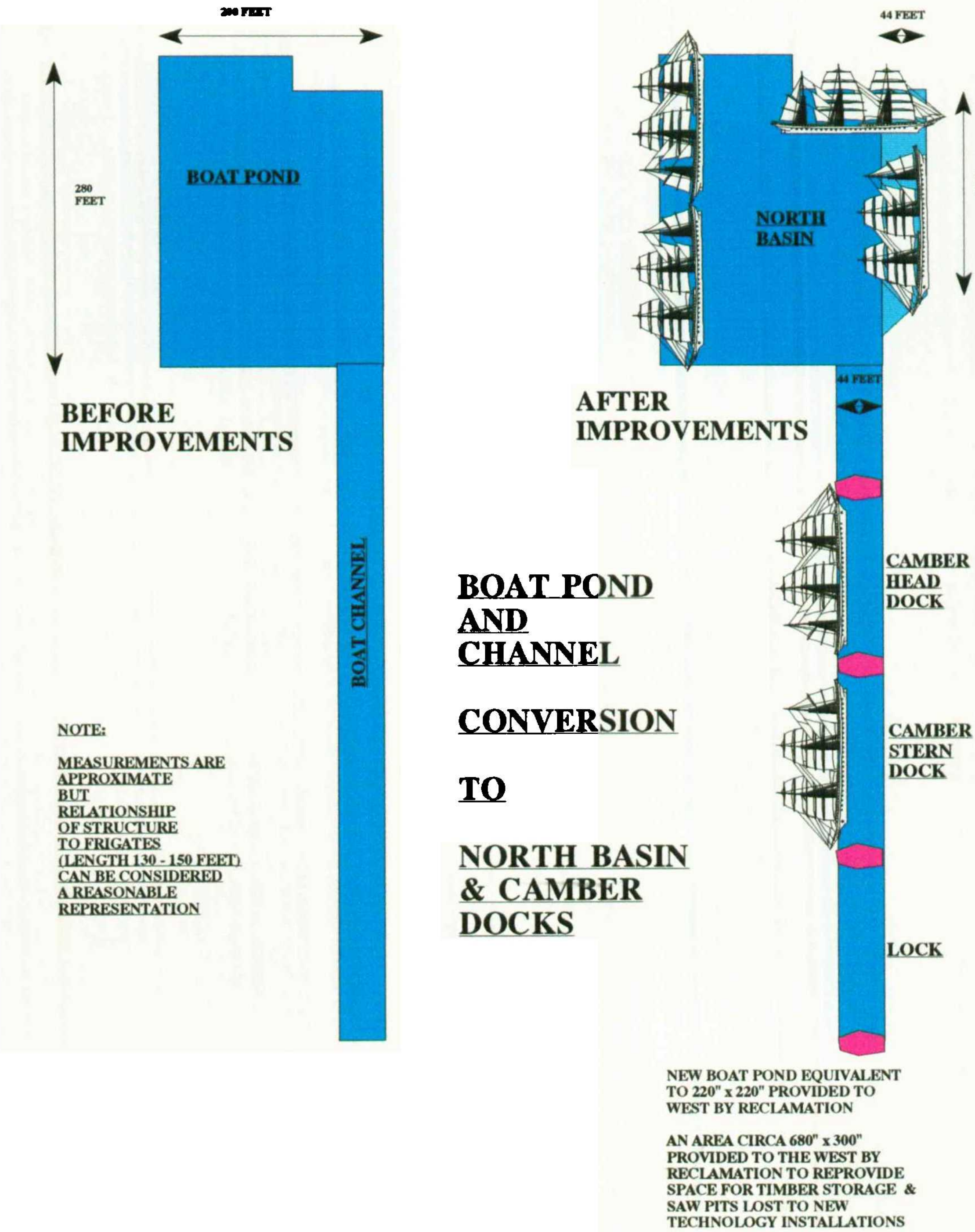
RESERVOIR AND BLOCK & WOOD MILLS - RELATIONSHIP

FIGURE 7.3.3

7.5.4. North Basin and Camber Docks. To provide better facilities for small ships and prevent them from using a dry dock which would have been better used by a large vessel, Bentham, in 1797[49] suggested using the North Boat Pond for fitting out frigates and the other smaller vessels. This Pond (see Figure 7.3.4) was connected to the Harbour by a long channel wide enough, but not deep enough, to take a 50 gun ship. By deepening the canal by four feet and adding three pairs of lock gates and drainage arrangements, a long dock capable of taking two Fifth or Sixth Rate frigates or three sloops or four gun-boats was made. The North Boat Pond, which was theoretically large enough to accommodate seven or eight frigates for fitting out, also had to be deepened before it could be used for vessels of this size but of course the entry or exit of ships from these berths could only be done when the channel was not in use as a dry dock. However the original estimated cost was only £6000[50] and Bentham had suggested that the work could be done in three to four months. On 5 November 1799, he was instructed by the Admiralty, to place the necessary contracts with Parlby's without delay[51] but unfortunately we do not know when the contractor actually started work or indeed when he finished. However, Morriss suggests that the facility was in use by the middle of 1801[52] and this indeed seems to fit in quite well with the earlier estimate of six months. In any event, it must surely rank as one of the most cost effective improvements in the history of the Naval Dockyards.

7.5.5. Increased Dry Dock Throughput. Taken together Bentham's schemes for the Dry Docks, the Reservoir and the North Basin/Camber Docks show a remarkable ingenuity in terms of space utilisation and minimisation of the construction work required to achieve it. Effectively, as the tables in Figure 7.3 show, the improvements provided a means to match the demand for dry dock time to the availability of it. Therefore, the improvements represented the basis on which further investment in the Yard could be justified since, unless the ships could be docked, the Dockyard could not take them and consequently much of the investment in other areas of the yard would have been questionable. Whilst none of the proposals involved extending the boundaries of technical knowledge they demonstrated not only a rare degree of situational appreciation and original thought but also very considerable skill in driving such novel changes through the corridors of power in Whitehall. Certainly they established Bentham as a power in the business of the Dockyards and, in so doing, they laid the grounds for his downfall since he must have undoubtedly upset the working practices of the Navy Board.

FIGURE 7.3.4


280
FEET
BOAT POND
BEFORE
IMPROVEMENTS
BOAT CHANNEL
NOTE:
MEASUREMENTS ARE
APPROXIMATE
BUT
RELATIONSHIP
OF STRUCTURE
TO FRIGATES
(LENGTH 130 - 150 FEET)
CAN BE CONSIDERED
A REASONABLE
REPRESENTATION
44 FEET
180
FEET
NORTH
BASIN
AFTER
IMPROVEMENTS
BOAT POND
AND
CHANNEL
CONVERSION
TO
NORTH BASIN
& CAMBER
DOCKS
CAMBER
HEAD
DOCK
CAMBER
STERN
DOCK
LOCK
NEW BOAT POND EQUIVALENT
TO 220" x 220" PROVIDED TO
WEST BY RECLAMATION
AN AREA CIRCA 680" x 300"
PROVIDED TO THE WEST BY
RECLAMATION TO REPROVIDE
SPACE FOR TIMBER STORAGE &
SAW PITS LOST TO NEW
TECHNOLOGY INSTALLATIONS

7.5.6. Caissons. Prior to the improvements the entrance to the Non-Tidal Basin was closed by two pairs of lock gates[53] while the Dry Docks had a single pair each which were hung on piers of masonry on either side of the entrance and between them was the entrance sill of wood, set on piles driven into the harbour bottom. As the masonry piers were not connected to each other (Figure 7.3.2) they tended to settle by different amounts; this caused the gates to move out of alignment and leak. Indeed, repairs and alterations to the Non-Tidal Basin entrance were part of the improvement plan for the Docks put forward by the Dockyard Officers; a scheme which was subsequently overtaken by Bentham's plans. In a letter of 4 August 1798, Bentham writes of an entrance made of masonry in a reversed arch shape and in addition "......for closing the Entrance, I would propose to make use of a hollow floating dam which when lying across the entrance should fit water tight being pressed against either the interior or exterior side of a groove formed in the Masonry according as the water is kept in or out."[54] The reversed arch shape for the entrance may have been under discussion for some time as a number of drawings for dock alterations still exist but unfortunately they are undated. A plan of the new South and double docks signed by Edward Tippett[55] on 21 August 1794 shows the traditional type of dock entrance[56], while a plan of the Basin and dock entrances signed by Bentham on 22 April 1796 shows the reversed arch shape[57]. The reversed arch made the piers and entrance sill into one continuous curve of masonry. This strengthened the entrance by tying the two sides of the dock together thus eliminating a cause of leaks whilst the masonry sill needed less maintenance than a wooden one. It can, with justification, be said that this was a civil engineering evolution rather than a technological innovation but it was nevertheless important.

The idea of a caisson or hollow floating dam is credited to George St. Lo who was Dockyard Commissioner at Chatham from 1703 to 1714[58] but although his device was built and given trials it was not adopted. However it is possible that as Bentham had been apprenticed to the Master Shipwright at Chatham he could have heard about St. Lo's idea. Bentham describes his idea as "......this floating dam which is built much in the form of a navigable vessel, is ballasted so as to float at an immersion of somewhat less than 20 feet, whereby as soon as there is 21 feet of water at the Entrance, the dam will have risen one foot which is sufficient to clear it out of the groove so as to admit of its being hauled away."[59] At 157 tons[60], it was a small hull by Royal Navy standards and, like any other, it was built of timber and coppered, the lowest part of the caisson contained 171 tons of ballast[61] and on the deck above the ballast were tanks which held sea water. The pressure of the water either externally or internally on the hull kept the caisson tightly against the masonry and thus closed the entrance. The tanks were emptied into the Harbour by gravity at low tide and any remaining water was pumped out until the caisson floated clear of the entrance and could be moved. This principle of floating or sinking a vessel by altering its buoyancy is of course how a submarine works.

The caisson's upper deck was strengthened so that it could be used as "a bridge of sufficient strength to bear the weight of the heaviest loaded carriages......."[62] This was not only convenient but saved the time taken to move men and materials around the Basin and associated Docks. The caisson was moved by 40 men, a considerable saving of manpower compared to the 90 men needed for operating the South Dock gates (No 1) or the 60 for the North Dock (No 6).[63]

Approved by the Admiralty in September 1798[64], the caisson was built by Portsmouth Dockyard and completed in 1801[65]. Fincham says that "Considerable opposition was made to the building of this caisson, on the supposition that it would not answer the purpose for which it was intended; and on the day when it was first removed, a great assemblage of persons appeared anxious to witness the operation: amongst them were the principal authorities in that branch of the service, and many naval officers. Apprehensions were, however, removed by decided success;....."[66] Certainly caissons not dock gates were fitted in the Boat Pond Canal[67] as well as the Non-Tidal Basin entrance and probably in the Camber to make unloading of supplies independent of the effects of the tide. The fact that caissons, although of a different design, are still in use in Portsmouth Harbour today demonstrates that both the idea and its implementation achieved all that was expected of it. Indeed caissons are now standard the world over in dry docks.

7.5.7. Seppings Apparatus. Not all the ideas for improving the movement of ships through the dry docks arose in the Inspector General's Office, an 'Apparatus for examining ships keels' was designed by the assistant to the Master Shipwright at Plymouth, Robert Seppings[68]. Traditionally, a ships' keel when dry docked rested on a line of piles of wooden blocks with the hull being kept upright by shores positioned against the dock walls. To allow the blocks to be removed so that the keel could be examined or worked on, the vessel had to be raised slightly by means of shores and wedges. This was expensive in time, manpower and timber and David Steel records that a Third Rate required 300 men working for about three days to make the keel accessible[69]. Seppings' apparatus dramatically reduced this to just 40 men working one twelve hour day.

Seppings' apparatus used ironshod wooden blocks with iron bolts running through the uppermost block. Under this were iron wedges which could be loosened or driven home with a ram. When the wedges were loosened, the uppermost block could be moved and allow ready access to the keel. The ship did not have to be lifted. The system was first tried at Plymouth in 1801, on a Third Rate, Canopus[70] and the other dockyards quickly followed. Portsmouth was certainly using the apparatus by 1803, as a letter of October 1802 to the Navy Board says "......we propose as directed by your warrant of 14th August last to dock Pigmy Cutter, when by placing her as near as maybe to one side, the Dock may be fitted with the Blocks above mentioned.......", these were "the blocks of Mr Seppings invention"[71].

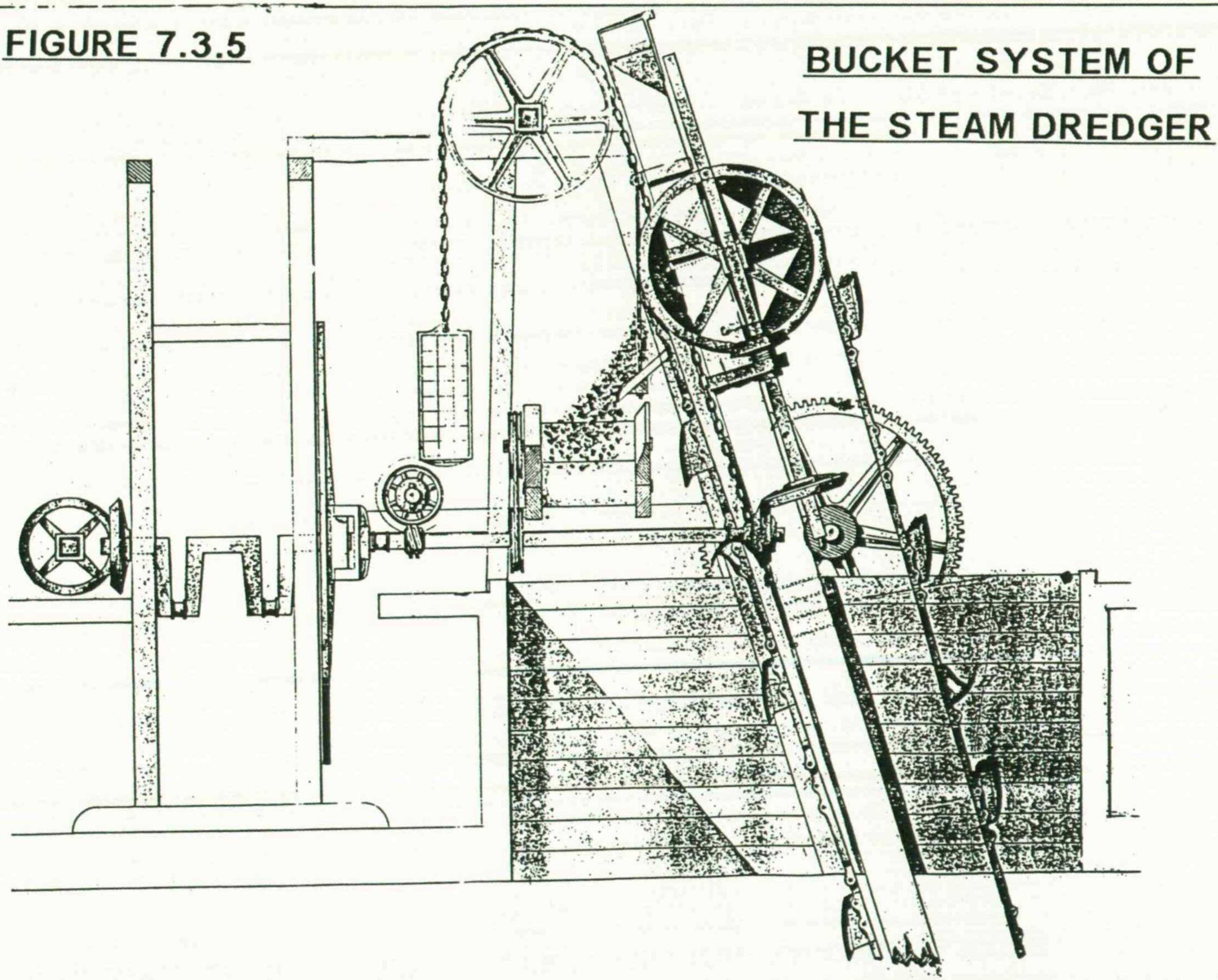
7.5.8. Dredgers. Bentham's design for a Steam Dredger was based on a lighter or similar dockyard craft and was about 100 feet long by 27 feet wide and had a draught of 9 feet with an adjustable bucket ladder, powered by a table-type steam engine, operated through an 18 foot by 8 foot well near the centre of the vessel. The object was to raise about 1000 tons of spoil in a 12 hour shift from a depth as much as 28 feet. Initially proposed in April 1800 because of the costs of manual dredging, Bentham revised his original design for a vessel with a flat sloping bow and bucket frame operating through a well in the stern, to a more conventional boat-shaped hull and the central well in June 1801 before work commenced on the vessel.

The bucket ladder was fixed at an inclined angle in the well and its frame was set in guides so that it could be raised or lowered to the appropriate working depth. The buckets, shown in Figure 7.3.5, were 48 ins wide and were attached to an endless loop of chain at either side which passed over drums at the top and bottom of the frame. Connected to the steam engine by shafting and bevel-gear wheels, the top drum rotated and moved the buckets around the frame. This is similar in design to the chain pumps discussed in Chapter 6. The bucket frame was counterbalanced, via a wheel and iron chain by a large weight.

Spoil raised in the buckets fell onto a moving belt set in an inclined trough extending over the side of the vessel, and on reaching the end of the trough, it dropped into barges secured alongside the Dredger. The moving belt was driven by a rope drive from a wheel mounted on the shafting between the steam engine and the bucket frame. This was raised and lowered with the aid of a drumhead - like that on a capstan - and flywheel in conjunction with the counterbalance. Links could be added to and removed from the chains to make them the correct length. The steam engine was a table type of 12hp which was built, with the rest of the machinery, by John Lloyd but the engine designer is unknown.

Built by Portsmouth Dockyard, the keel of the Dredger was laid in July 1801 and the vessel was launched in November 1802. As she was being prepared for trials of her machinery, supervised by the Foreman of the Millwrights, a crew to man and operate her became necessary. Bentham's recommendation for the man to be in charge was William Mortimer who had been a scavelman and thus had considerable knowledge of the harbour; plus a crew of two more scavelmen and four labourers.. However dispensation for this appointment[72] had to be given by the Admiralty Board, since in September 1802, it had forbidden the employment of scavelmen or riggers on dockyard craft. Mortimer must have been successful in being appointed since the records show the Dockyard recommending a suitable man for promotion after his death in 1815[73]. In any event, trials were completed by May 1803 when Bentham reported to the Admiralty Board that the Dredger could "fully to answer its intended purpose" and was raising 2 tons of soil a minute[74].

FIGURE 7.3.5



BUCKET SYSTEM OF THE STEAM DREDGER

7.6 Metal Works. The principal metalworking facility was the Metal Mills but in addition there were the smiths' shops and the foundries.

7.6.1. Metal Mills Table 7.4 shows the progression of the metalworking facilities from inception to full production and Figure 7.4 shows diagrammatically the rate of progress with that development. Figure 7.4.1 show 4 "snapshot" extracts from the Dockyard Plans of 1793, 1796, 1805 and 1810/14 - these being the dates of the plans that are available for inspection today. In looking at Figure 7.4.1 it is necessary to bear in mind that what is shown is a mixture (at the time the plan was produced) of what actually existed and what was then being proposed. However by examining all four plans as a whole, alongside Figure 7.4, it is possible to achieve a reasonable appreciation of the development throughout the period.

The complex which became known as the Metal Mills originated in 1797 as a proposal for a small melting furnace to solve the problems of dealing with old copper sheathing removed from ships in Portsmouth[75] but, as Figure 7.4 shows "on-site" construction work did not commence until 1802. Until 1797, the dockyard practice was to burn off weeds and other detritus using furze for fuel and then return the copper to the contractor who had originally supplied it for re-cycling. Against this background, the rationale for the 1797 proposal was that the cost of the furnace, estimated at £100, would be off-set by reductions in labour and fuel costs and losses of copper metal during the burning process[76].

There was sufficient interest in the plan for the Dockyard to initiate trials of burning and melting using 5 cwt of copper[77] but unfortunately there are no details of how this was done, or what type of furnace was used - cupola or reverberatory. In fact, it is clear from surviving drawings[78] of the Metal Mills that reverberatory furnaces were acquired to heat both copper and iron and a cupola was used to recover copper metal from the furnace slag[79]. However the decision to acquire the melting furnace was not implemented until August 1802, as the Navy Board had quietly shelved the project considering that it had been ".....completely set aside by the result of the trial that was made at Portsmouth Yard......and which was so materially in favour of the usual mode of managing that article, that we took for granted (the more especially as the subject had laid dormant for upwards of three years) that the General's project had been entirely at rest[80]".

TABLE - 7.4

NOTE ORGANISATIONS - AB - Admiralty Board, NB - Navy Board, IG - Inspector General of Dockyards. SB- Bentham, SG - Goodrich, MB - Brunel, PD Portsmouth Dockyard Officers

TO REFINE OLD COPPER SHEATHING & SUBSEQUENTLY RE-MANUFACTURE THE SHEETING

CROSS REFERENCE TO FIGURE 7.1	DATE DAY/MNTH	YEAR	FROM (ORG.)	TO (ORG.)	REFERENCE	SUBJECT MATTER	REMARKS
PA1	07-Nov	1797	IGO	AB	ADM1/3525	To refine old Cu sheathing	Returned to contractors after burning with furze
TD1	09-Dec	1797	NB	PD	ADM/Q/3320	Portsmouth to conduct trial on half ton copper	
TD1	03-Mar	1798	IGO	AB	ADM 1/3525	Bentham's comments on Dockyard's trials	Five hundredweights (5cwt) Copper used
PA1	12-Apr	1800	IGO	AB	ADM 1/3525	Reasons to re-manufacture old Cu in Dockyard	
PA5	27-Jun	1801	AB	NB	ADM/Q/3321	Give orders to Portsmouth about copper refining	Also inform Mr Williams - contractor
	31-May	1802	AB	NB	ADM/Q/3321	Why has large reward been given to Plymouth shipwright?	Value of copper lost during burning
PA3	19-Jun	1802	NB	AB	ADM/Q/3321	Explanation of why furnaces have not been built	Assume scheme in abeyance after Portsmouth trial
PA5	02-Aug	1802	AB	NB	ADM/Q/3321	To proceed with plan set out in 27 June 1801	All copper to be sent to Portsmouth pro tem
PA5	05-Aug	1802	NB	IGO	ADM 106/2539	Bentham to send Navy Board plans etc	Admiralty approval given 2/8/1802
ID1	14-Aug	1802	NB	IGO	ADM 106/2539	Navy Board agree P'mth's choice of site	Furnace can go next to Blacksmiths shop
MD2	13-Oct	1802	NB	IGO	ADM 106/2539	Applications to manage Cu refining	Also 18/20/23/27 Oct and 18/22 Nov 19 names
MD3	03-Mar	1803	IGO	AB	ADM 1/3526	W E Sheffield is Bentham's choice for post	Admiralty approval 14 Nov 1803
	04-May	1803	Whitmore & Co	IGO	ADM/Q/3322	Whitmore's quotation for Metal Mills equipment	Steam engine and rolling machinery
PA1	03-Jan	1803	IGO	AB	ADM/Q/3322	Proposal to re-manufacture old Iron	Could run on same steam engine as Copper rolls
	03-Aug	1803	AB	NB	ADM/Q/3322	Total estimated costs for Copper & Iron works	Could be ready to use in 10 months from recieving order
ID3	09-Sep	1803	IGO	AB	ADM 1/3526	Lately erected furnace used to melt 4 tons Cu sheathing	Cost of recycling
	13-Sep	1803	AB	NB	ADM/Q/3322	All old sheathing in store to be re-manufactured	NB note- Is P'mth ready to re-manufacture old Copper?
ID3	05-Oct	1803	IGO	AB	ADM/Q/3322	Report on copper refining seen by Bentham at Portsmouth	Better to refine all sheathing at Portsmouth
CN3	09-Feb	1804	NB	IGO	ADM 106/2539	P'mth to recieve cast iron items & pay freightage	
	27-Mar	1804	AB	IGO	ADM 1/3527	Query re delays to Cu rolling machinery	AB note - when will it be ready
CN3	18-Apr	1804	IGO	AB	ADM 1/3527	Delays in supply of machinery from B'ham	Due Feb, part sent early April, rest in Sept
MD4	27-Apr	1804	PD	NB	POR/D/27	P'mth ask for Sheffield to be put on Extra Paybooks	Warrant of 12 Dec 1803 - ADM 42/1328
CN2	08-Jun	1804	NB	IGO	ADM 106/2539	Cast Iron pipes from Littlewood's Foundry	Forwarded by Deptford
ID2	12-Aug	1804	NB	IGO	ADM 106/2539	Bill from Gould's of Truro for castings	
	16-Jan	1805	IGO	AB	ADM 1/3527	Progress with Metal Mills	Parts broken in transit to be replaced. Cu rolls nearly ready and 100 tons Cu to be processed
	19-Jan	1805	AB	NB	ADM/Q/3322	Further 200 tons old sheathing to be issued to contractors	Contractors have recieved 150 tons since 20 Sept 1803
CN4	02-Feb	1805	NB	IGO	ADM 106/2539	Payment requested for machinery from Whitmore	Whitmore to get £3000 in part payment
MN1	19-Feb	1805	IGO	AB	ADM/Q/3323	Proposed manning and pay rates for Metal Mills	
MD2	30-Apr	1805	SB	NB	POR/D/27	Appointment of Metal Mill Master in train	Master Millwright to supervise Metal Mills pro tem
CN1	06-May	1805	IGO	AB	ADM 1/3527	Screwcutting Lathes needed for making Cu bolts	AB note of 20 May - Brunel to order, expense approved
TD1	02-Sep	1805	SG		Goodrich B10	Trial on rolling Copper sheathing	Observed by Goodrich and Dockyard officers
CN2	11-Sep	1805	NB	IGO	ADM 106/2539	Boiler arrived from Whitmore's of B'ham	Give instructions to Whitmore re fixing it.
ID2	19-Sep	1805	NB	IGO	ADM 106/2539	Bill from Henckell & Co for items supplied	
	07-Oct	1805	NB	IGO	ADM 106/2539	Apparatus for cutting screws in Cu bolts at Deptford	To be forwarded to Portsmouth
	21-Nov	1805	SG		Goodrich B10	Temple Mill Copper melter requests Dockyard employment	Employed with mate, 7 Dec 1805 (B12)
MD2	19-Dec	1805	NB	IGO	ADM 106/2539	Complaint by Grenfell of Temple Mill	Are refiners employed in Metal Mills?
	23-Dec	1805	SG		Goodrich B12	Discussions with Navy Board re Grenfell's complaint	

246a.

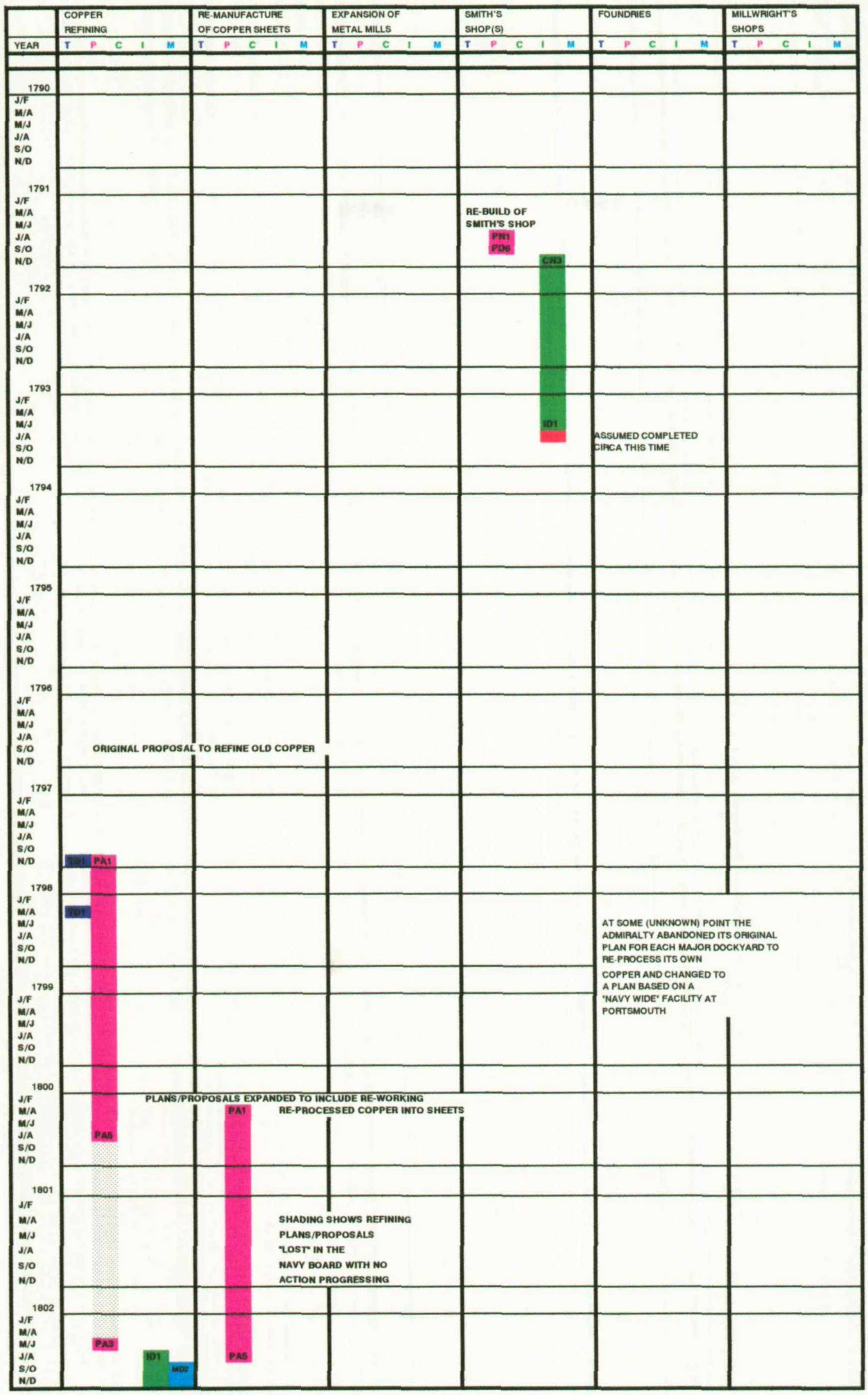

YEAR
COPPER REFINING
RE-MANUFACTURE OF COPPER SHEETS
EXPANSION OF METAL MILLS
SMITH'S SHOP(S)
FOUNDRIES
MILLWRIGHT'S SHOPS
T P C I M
1790
1791
1792
1793
1794
1795
1796
1797
1798
1799
1800
1801
1802
J/F
M/A
M/J
J/A
S/O
N/D
RE-BUILD OF SMITH'S SHOP
PN1
PD6
CN3
ID1
ASSUMED COMPLETED CIRCA THIS TIME
ORIGINAL PROPOSAL TO REFINE OLD COPPER
TD1
PA1
AT SOME (UNKNOWN) POINT THE ADMIRALTY ABANDONED ITS ORIGINAL PLAN FOR EACH MAJOR DOCKYARD TO RE-PROCESS ITS OWN COPPER AND CHANGED TO A PLAN BASED ON A 'NAVY WIDE' FACILITY AT PORTSMOUTH
PLANS/PROPOSALS EXPANDED TO INCLUDE RE-WORKING RE-PROCESSED COPPER INTO SHEETS
PA5
SHADING SHOWS REFINING PLANS/PROPOSALS "LOST" IN THE NAVY BOARD WITH NO ACTION PROGRESSING
PA3
MD2

FIGURE 7.4

TABLE - 7.4
CONTINUED

NOTE ORGANISATIONS - AB - Admiralty Board, NB - Navy Board, IG - Inspector General of Dockyards. SB- Bentham, SG - Goodrich, MB - Brunel, PD Portsmouth Dockyard Officers

TO REFINE OLD COPPER SHEATHING & SUBSEQUENTLY RE-MANUFACTURE THE SHEETING - continued

CROSS REFERENCE TO FIGURE 7.1	DATE DAY/MNTH	YEAR	FROM (ORG.)	TO (ORG.)	REFERENCE	SUBJECT MATTER	REMARKS
MD2	24-Jan	1806	NB	IGO	ADM 106/2539	Reply to Grenfell's letter re seducing workmen to Dkyd	
	05-Mar	1806	AB	NB	ADM/Q/3323	Another flywheel to be obtained at price of 20/- per cwt	Navy Board to order from Henekell & Co Wandsworth
	18-Jun	1806	SG	AB	ADM 1/3527	Items needed to complete Metal Mills machinery	
CN1	24-Jun	1806	NB	IGO	ADM 106/2539	Order items from Whitmores to estimated prices	Letter of 18/6 and Adty Board of 19/6/1806
CN3	26-Jun	1806	NB	IGO	ADM 106/2539	Henckell and Co deliver flywheel. Please inspect	Reminder sent 1 Aug 1806
	24-Jul	1806	NB	IGO	ADM 106/2539	Explain why Whitmore's bill exceed estimates so much	
MD2	26-Jul	1806	SG	NB	POR/D/27	Expenses for Beach's recruiting trip to B'ham 12/05	
	08-Aug	1806	NB	IGO	ADM 106/2539	Beach's expenses to be paid	Directions given to Clerk of Cheque
CN3	26-Aug	1806	NB	IGO	ADM 106/2539	P'mth to recieve ordered items from Whitmore	
	13-Sep	1806	AB	NB	ADM/Q/3323	Whitmore's bill to be paid	Extra cost on Whitmore's bill
	03-Nov	1806	SG	NB	POR/D/28	Death of Samuel Beach	
MD2	07-Nov	1806	SG	PD	ADM 106/2539	Appointment of new Metal Master	From Goodrich to Commissioner Grey
	08-Dec	1806	SG		Goodrich B16	New flywheel for second shaft	Just completed and at work
	28-Dec	1805	SG		Goodrich B17	Crank of steam engine loose	Metal mills must be stopped for repairs
MD4	13-Feb	1807	SG	AB	ADM 1/3527	Hamlet Vernon to succeed Beach as Master of Metal Mills	
	19-Feb	1807	SG		Goodrich B17	Steam engine crank repaired	Metal Mills working again
	02-Mar	1807	AB	NB	ADM/Q/3323	Need to reply to Grenfell & Williams letter	P'mth to give info on re-manufacturing Copper
ID3	11-Jun	1807	PD	NB	POR/D/28	Metal Mills working at night	More lamp oil needed
	23-Jun	1807	SG	AB	ADM/Q/3323	Detailed reply to Grenfell & Williams letter	Also amount and costs of Copper rolled in 1 week
TD1	08-Jul	1807	SG		Goodrich B18	Trial rolling of Copper bolts	To test steam engine power output was adequate
	21-Aug	1807	NB	IGO	ADM 106/2539	Whitmore's offer to make two wrought iron boilers	
PD6	21-Sep	1807	SG	AB	ADM 1/3527	Proposal to use rolls to make Cu bolts	Rolls originally intended for Iron
	09-Oct	1807	NB	IGO	ADM 106/2539	When did Mr Sheffield die?	
	04-Apr	1808	IGO	AB	ADM 1/3527	Plymouth's request for refining furnace	Better to send all copper to Portsmouth
	07-Dec	1808	PD	NB	POR/D/28	Gudgeon on Flywheel broken	Fontley Forge will repair, about 1 week. (1713)

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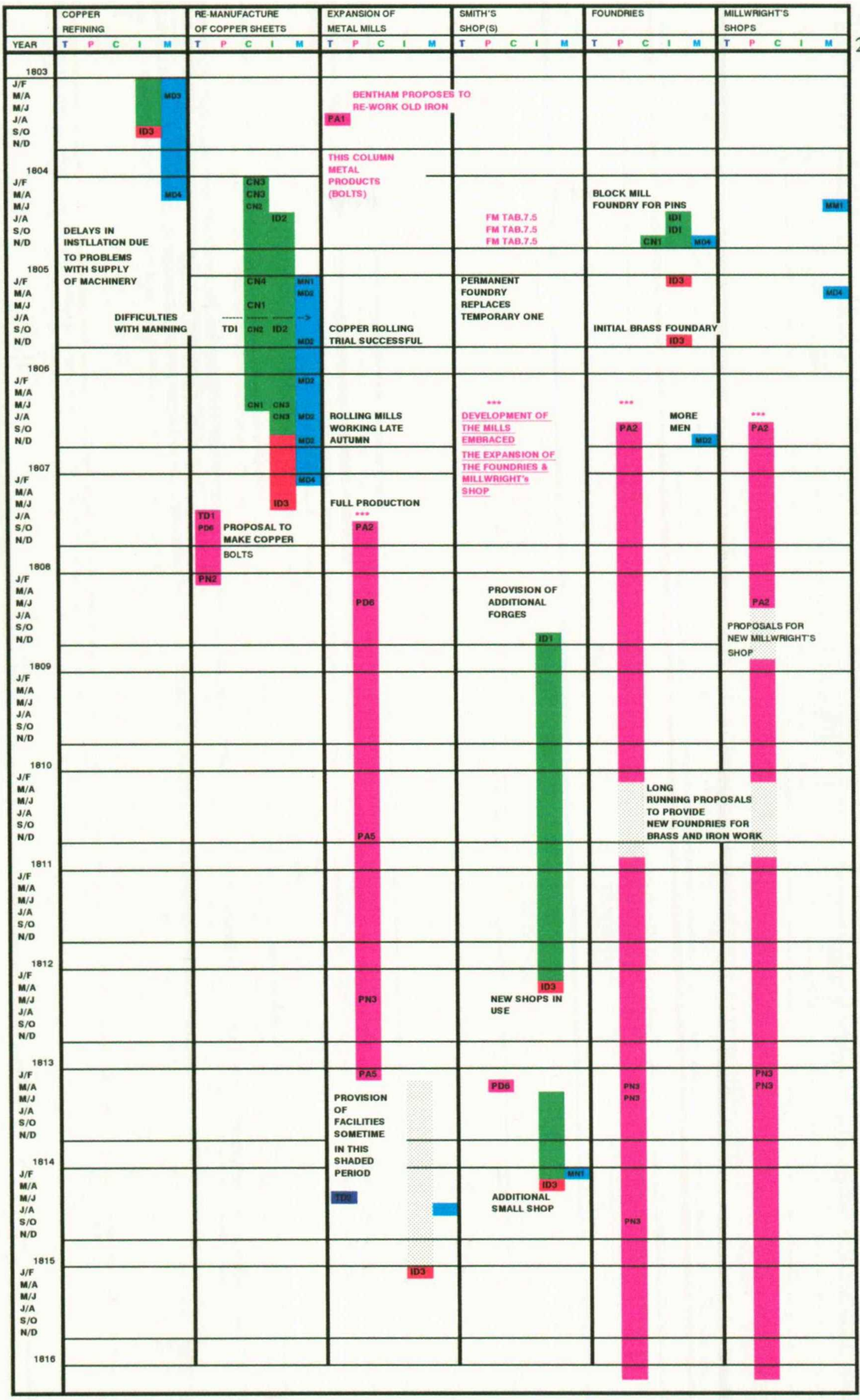

FIGURE 7.4 (Continued)

CROSS REFERENCE TO FIGURE 7.1	DATE DAY/MNTH	YEAR	FROM (ORG.)	TO (ORG.)	REFERENCE	SUBJECT MATTER	REMARKS
	NOTE ORGANISATIONS - AB - Admiralty Board, NB - Navy Board, IG - Inspector General of Dockyards. SB- Bentham, SG - Goodrich, MB - Brunel, PD Portsmouth Dockyard Officers						
	TO ALTER AND EXTEND PORTSMOUTH METAL MILLS						
PA2	06-Oct	1807	NB	IGO	ADM 106/2539	Portsmouth will be told to erect furnaces	To be used for rolling Copper bolts
PD6	17-May	1808	IGO	AB	ADM 1/3527	Proposals to alter and extend Metal Mills	Admiralty requests accurate estimates
	17-Jul	1809	PD	NB	POR/D/26	Statement about stolen Copper	By Master of Metal Mills
	04-Jun	1810	PD	NB	POR/D/28	Fire in roof of Metal Mills	Also 5 June 1810
	23-Nov	1810	PD	NB	POR/D/28	When can Metal Mills make Cu bolt staves?	Reply to query of 21 Nov - not able to say
	16-Jul	1811	PD	NB	POR/D/29	Small roof fire above rolling mills	
PN3	02-Jun	1812	PD	NB	POR/D/29	Quantity of new Cu nails that can be made from old	
PA5	05-Feb	1813	PD	NB	POR/D/29	Need for more details for Metal Mills/Millwrights shop	Orders of 31 Oct 1810' have outline plans only
	15-Apr	1813	PD	NB	POR/D/29	Kingston's proposal to cast anchors	Mixed metal, model sent for consideration
	02-Jun	1813	PD	NB	POR/D/29	Reply by Vernon re available space	Drying stove, large furnace, crane for moulds etc.
	01-Nov	1813	PD	NB	POR/D/30	Cost of extracting Copper from slag	
TD2	01-Jun	1814	PD	NB	POR/D/30	Report on rolling Fe and Cu bolt staves	From Hamlet Vernon
MD2	25-Jul	1814	PD	NB	POR/D/30	Suitable workman available at Fontley	Reference from Jellicoe - 21/7/1814 (1713)
ID3	23-Feb	1815	PD	NB	POR/D/30	Warrant of 26 Jan to make bolt staves with rolls	Adjustments needed in changing from Cu to Fe
	SMITHS						
PN1	04-Aug	1791	PD	NB	POR/D/26	Site of new Smith's shop	
PD6	23-Aug	1791	PD	NB	POR/D/26	Proposal for 50 ton capacity water tank for Smiths shop	Will hold 2-3 days supply and cost £165
CN3	06-Dec	1791	PD	NB	POR/D/26	Request for Portland stone for Smiths shop	
ID1	13-Jun	1793	PD	NB	POR/D/26	Cast iron pipes from Engine House to Smiths shop	Jellicoe could supply 1000ft of 6ft X 3ins diam + bolts
	08-Sep	1810	SG		Goodrich B23	Alterations/additions to Smiths shop	Sketch of proposals
	03-May	1811	PD	NB	POR/D/28	Unable to repair mooring chains, all forges in use	
ID1/ID3	27-Feb	1812	PD	NB	POR/D/29	Additional Smiths shop built since 8 Dec 1808	Contains 10 fires and employs 35 men
PD6	19-Mar	1813	PD	NB	POR/D/29	Propose adding to small Smiths shop East of Coal Yard	Would increase small fires to 20
MN1/ID3	29-Jan	1814	PD	NB	POR/D/30	Request to promote 12 Hammermen to 3rd class Firemen	New detached smithy ready for workmen
	04-May	1814	PD	NB	POR/D/30	Suggestion that Smiths could re-manufacture old Iron	

TABLE - 7.4
CONTINUED

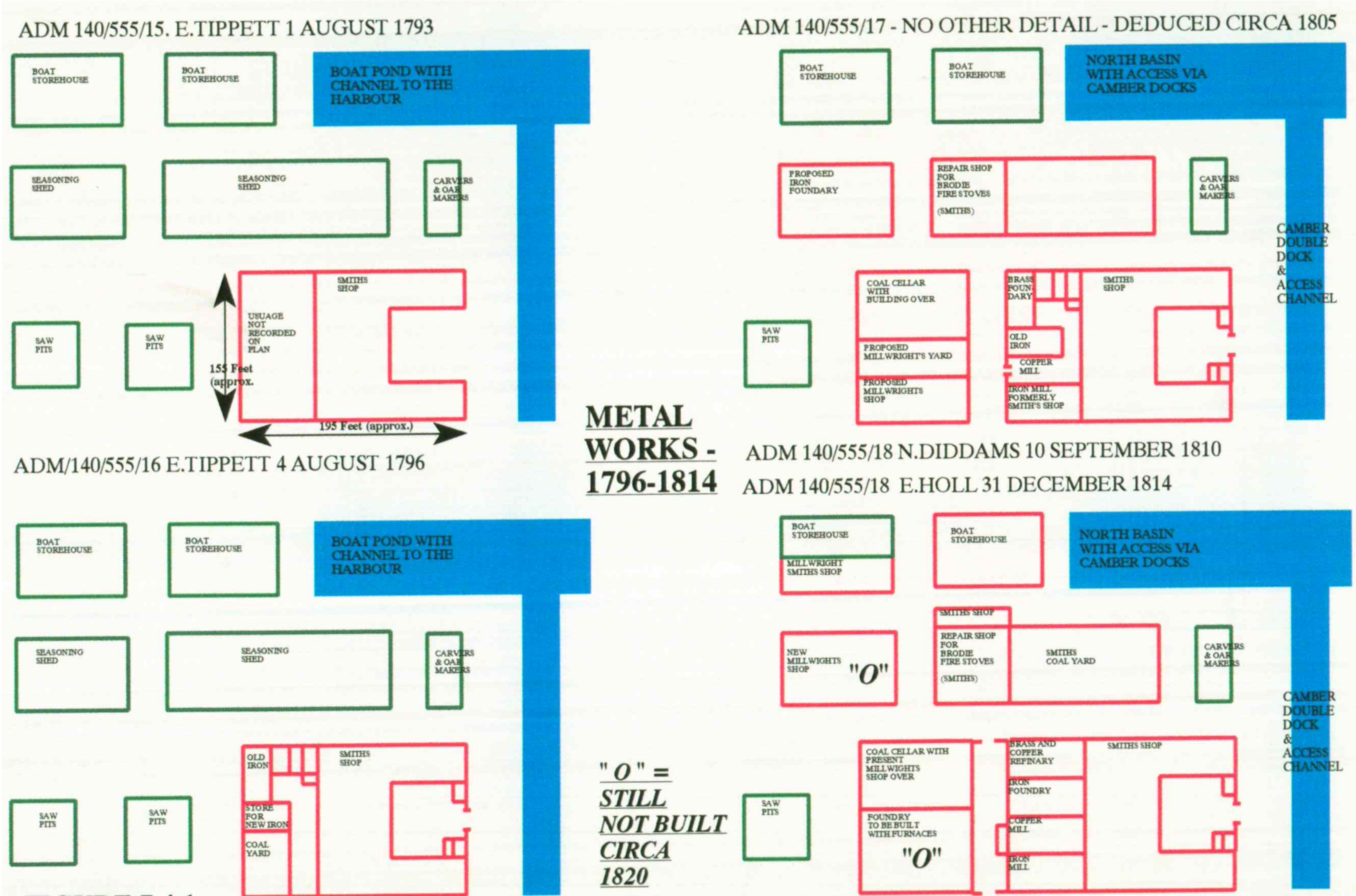
ADM 140/555/15. E.TIPPETT 1 AUGUST 1793
BOAT STOREHOUSE
BOAT STOREHOUSE
BOAT POND WITH CHANNEL TO THE HARBOUR
SEASONING SHED
SEASONING SHED
CARVERS & OAR MAKERS
SMITHS SHOP
USUAGE NOT RECORDED ON PLAN
SAW PITS
SAW PITS
155 Feet (approx.)
195 Feet (approx.)
ADM/140/555/16 E.TIPPETT 4 AUGUST 1796
BOAT STOREHOUSE
BOAT STOREHOUSE
BOAT POND WITH CHANNEL TO THE HARBOUR
SEASONING SHED
SEASONING SHED
CARVERS & OAR MAKERS
OLD IRON
SMITHS SHOP
STORE FOR NEW IRON
COAL YARD
SAW PITS
SAW PITS
METAL WORKS - 1796-1814
" O " = STILL NOT BUILT CIRCA 1820
ADM 140/555/17 - NO OTHER DETAIL - DEDUCED CIRCA 1805
BOAT STOREHOUSE
BOAT STOREHOUSE
NORTH BASIN WITH ACCESS VIA CAMBER DOCKS
PROPOSED IRON FOUNDARY
REPAIR SHOP FOR BRODIE FIRE STOVES (SMITHS)
CARVERS & OAR MAKERS
CAMBER DOUBLE DOCK & ACCESS CHANNEL
COAL CELLAR WITH BUILDING OVER
PROPOSED MILLWRIGHT'S YARD
PROPOSED MILLWRIGHTS SHOP
BRASS FOUN-DARY
OLD IRON
COPPER MILL
IRON MILL FORMERLY SMITH'S SHOP
SMITHS SHOP
SAW PITS
ADM 140/555/18 N.DIDDAMS 10 SEPTEMBER 1810
ADM 140/555/18 E.HOLL 31 DECEMBER 1814
BOAT STOREHOUSE
MILLWRIGHT SMITHS SHOP
BOAT STOREHOUSE
NORTH BASIN WITH ACCESS VIA CAMBER DOCKS
NEW MILLWIGHTS SHOP
"O"
SMITHS SHOP
REPAIR SHOP FOR BRODIE FIRE STOVES (SMITHS)
SMITHS COAL YARD
CARVERS & OAR MAKERS
CAMBER DOUBLE DOCK & ACCESS CHANNEL
COAL CELLAR WITH PRESENT MILLWIGHTS SHOP OVER
FOUNDRY TO BE BUILT WITH FURNACES
"O"
BRASS AND COPPER REFINARY
IRON FOUNDRY
COPPER MILL
IRON MILL
SMITHS SHOP
SAW PITS

FIGURE 7.4.1

TABLE - 7.4
CONTINUED

CROSS REFERENCE TO FIGURE 7.1	DATE DAY/MNTH	YEAR	FROM (ORG.)	TO (ORG.)	REFERENCE	SUBJECT MATTER	REMARKS
	NOT ORGANISATIONS - AB - Admiralty Board, NB - Navy Board, IG - Inspector General of Dockyards SB- Bentham, SG - Goodrich, MB - Brunel, PD Portsmouth Dockyard Officers						
	TO ALTER AND EXTEND PORTSMOUTH METAL MILLS - continued						
	FOUNDRIES						
ID1	31-Aug	1804	IGO	AB	ADM 1/3527	New foundry will not be ready for several months	Get coaks from Maudslay as present foundry busy
ID1	25-Oct	1804	NB	IGO	ADM 106/2539	New foundry will soon be ready	
CN1	07-Nov	1804	NB	IGO	ADM 106/2539	Bentham to order tools & materials & employ Founder	For coak founding
MD4	28-Nov	1804	NB	IGO	ADM 106/2539	Portsmouth directed to enter and pay Founder	
ID3	16-Jan	1805	IGO	AB	ADM 1/3527	Permanent Foundry & Refinery started	Report on progress on Metal Mills
ID3	01-Nov	1805	SG		Goodrich B10	Brass furnaces at Metal Mills nearly complete	
PA2	24-Sep	1806	NB	IGO	ADM 106/2539	Admiralty order for Iron Foundry on New Ground	Please send estimates and plans
MD2	13-Nov	1806	SG		Goodrich B16	More men needed at Brass Foundry	
	22-Mar	1808	SG		Goodrich B18	Description + sketch of proposed Brass Foundry	See also 16 April 1808 (B20)
	16-Jul	1810	SG		Goodrich B22	Another minute sent re completion of Foundries	Brass and Iron
PN3	01-Mar	1813	PD	NB	POR/D/29	Plans awaited for Brass and Iron Foundry	Reply to 24 Feb 1813 re progress on Metal Mills
PN3	09-Jun	1813	PD	NB	POR/D/30	Still no plans for Brass Foundry	
PN3	07-Sep	1814	PD	NB	POR/D/30	Request re future work for Brass Foundry	To supply heavy castings
	MILLWRIGHTS						
MN1	15-May	1804	SG		Goodrich B9	Proposed establishment of Millwrights	Current location of Millwrights shop
MD4	30-Apr	1805	PD	NB	POR/D/27	Master Millwright James Linaker in post	Also ADM/42/1330/2 Second quarter of 1805
	05-Jun	1805	NB	IGO	ADM 106/2539	Order bellows from Lloyd's	For Millwrights shop and Block pin forge
PA2	24-Sep	1806	NB	IGO	ADM 106/2539	AB order for Millwrights shop & pound on New Ground	Please send estimates and plans
	07-Apr	1808	SG		Goodrich B20	Sketch of proposed Millwrights shop recieved from Linaker	
PA2	17-May	1808	IGO	AB	ADM 1/3527	Millwrights shop proposed as part of Metal Mills alterations	Approved proposal from Goodrich letter of 21/9/1807
	16-Jul	1810	SG		Goodrich B22	Another minute re completion of Millwright Smiths shop	
PN3	05-Feb	1813	PD	NB	POR/D/29	Outline plans for Metal Mills & Millwrights shop	More details needed, orders of 31/10/1810
PN3	01-Mar	1813	PD	NB	POR/D/29	Progress with smiths shop for Millwrights	Small engine, boring machine, 6 forges,3 lathes

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This seems to be a remarkably weak attempt to save the Board's face following the discovery of its inaction on this matter. By this time, the original proposal had been incorporated into a more far-reaching scheme to improve the quality and life of the copper sheathing as a consequence of the Royal Dockyards undertaking the re-cycling of the copper themselves rather than returning it to the contractors. It is noteworthy that the original concept involved other Dockyards, besides Portsmouth[81], being involved in the re-cycling of copper although it is probable that as early as 1802/1803 it had been decided, at least in the short term, to concentrate on Portsmouth.

The site selected within Portsmouth Dockyard was close to the Smiths shop which had been rebuilt and enlarged in the early 1790s on a part of the Yard site mainly used for timber seasoning and sawpits. (See Figure 7.4.1). Following approval in August 1802 to proceed with the more ambitious plan, the major part of the equipment and a steam engine were ordered from Whitmore and Son of Birmingham. Progress was slow although the melting furnace was completed and in operation first in September 1803[82], subsequently the rolling machinery and steam engine arriving throughout 1804 and the early months of 1805. That there were delays in the arrival and setting up of the Metal Mills machinery is confirmed by this comment on a letter from the Admiralty Board, "...... Direct General Bentham to report what circumstances have delayed the erection of the machinery for rolling copper and when will it be in readiness?"[83]

Bentham's reply of 18 April 1804[84] explains that machinery which should have left Birmingham in February was only just being dispatched and much of it would not arrive until September. This was due to problems with the manufacturer's workmen who had to exercise with the Volunteers. This would seem a reasonable explanation given that the threat of invasion by Napoleon's forces was not to fade finally until after the Battle of Trafalgar in 1805 - up to then the Volunteers were an essential part of Britain's defences. By early 1805, Bentham was explaining that although most of the steam engine and rolling machinery was erected, two boiler parts which had been broken in transit, were being re-cast at the carrier's expense[85]. These two incidents serve to remind us that progress in introducing new technologies was invariably subject to factors outside the control of those concerned.

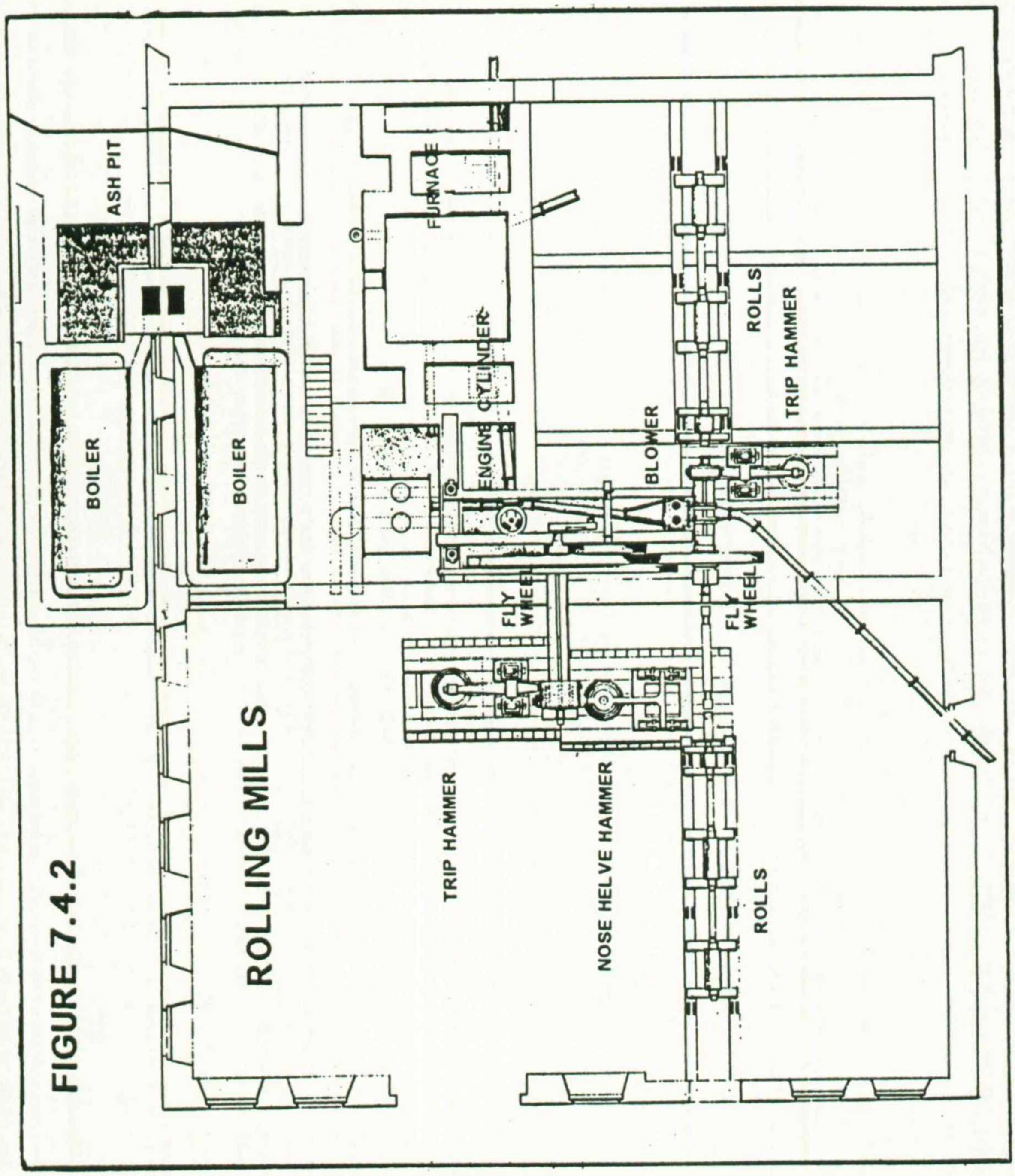

ROLLING MILLS
ASH PIT
BOILER
BOILER
FURNACE
ENGINE CYLINDER
BLOWER
ROLLS
TRIP HAMMER
FLY WHEEL
FLY WHEEL
TRIP HAMMER
NOSE HELVE HAMMER
ROLLS

FIGURE 7.4.2

By the late autumn of 1805 the rolling mills were finally working (Figure 7.4.2) and in June 1806 the last ancillary pieces of equipment and spares were ordered[86]. These were received from Whitmore's in August 1806[87] and included a stamping press, a second pair of shears for cutting copper and spare rolls. A screw-cutting lathe for use in the manufacture of copper bolts had been purchased the year before in 1805[88] and this marked a further expansion in the ambitions for the plant.

The process of recruiting the necessary skilled workmen for the Metal Mills started in the autumn of 1802, when the Navy Board and Bentham considered the merits of nineteen applicants[89] to manage the copper refining at Portsmouth. Out of these, there were only two serious contenders and the post was given, at Bentham's request, to W.E.Sheffield[90], duly confirmed by his entry on the Dockyard paybooks[91]. His name disappears from the Dockyard paybooks in late 1805[92] and no appointment to replace him seems to have been made and thus it is likely that his responsibilities would have been included with those of the Master of the Metal Mills.

In 1805, Samuel Beach was appointed as Master of the Metal Mills[93] and part of his job was recruiting men to operate the machinery then being installed for rolling copper sheathing. In his search for the skilled men he needed, Beach travelled to Birmingham[94] and despite difficulties, he would appear to have been successful since the manpower was evidently in place by the time the plant was ready to operate[95]. In fact, Beach was almost too successful as his trip was immediately followed by the Navy Board receiving a letter of complaint from a firm called Grenfells saying that refiners had been "....seduced away from Temple Mills for the service of Portsmouth Yard......." The Navy Board was forced to investigate this allegation[96] but Goodrich's Journal shows that the workmen, a copper melter and his mate had approached the Dockyard and offered to work there[97]. The workmen were employed at the Metal Mills and after some initial difficulties, proved to be thoroughly competent. However the incident undoubtedly confirms that at this time, as now, skill shortages in the new technological fields were a matter of serious concern. At the management level, the Dockyard was unlucky in losing Beach (who died in October 1806[98]) so soon after taking up his appointment. After advertisements were placed in the newspapers Hamlet Vernon[99] who was known to Goodrich, having worked at Fontley Forge for nine years, was appointed Metal Master on 20 February 1807[100]. It can be claimed therefore, with some justification given Fontley's close association with Portsmouth

Dockyard, that Vernon was one of the first senior new "technologists" to emerge from within the Dockyard system.

Quite the most difficult problem for the Navy Board was finding the optimum moment to cease purchasing the bulk of the copper sheathing from the contractors and switch to dependence on the new facilities at Portsmouth. Too soon, and there would be a shortage of sheathing, too late and Navy would be paying twice. As it was, they stockpiled old sheathing in the Dockyards ready for operating the Metal Mills, but delays in the installation of the machinery meant that they had to release some of the old copper to the contractors to safeguard the supply. In a note dated 18 January 1805[101], the Admiralty authorized the Navy Board to issue old copper to contractors at the real market price.

No detailed figures for output of copper have come to hand, but by 1807, Portsmouth was producing 800 tons of sheathing annually which Goodrich states was about two-thirds of the Navy Board average annual usage for 1804-06 of 1172 tons of sheathing and 514 tons of bolts. A year later, when making a case for **not** erecting a melting furnace at Plymouth, which had been the (early) original intention, Bentham stated that the capacity of the Portsmouth melting furnace was 1000 tons annually and that it was operated with two gangs of refiners[102] producing a two ton charge in a twelve hour shift[103]. Given that a significant amount of copper supplied to the fleet was not recoverable for re-cycling, it would seem that by around 1808 Portsmouth was probably able to handle the totality of the material recovered from the fleet. Thus from the relatively modest ambitions for copper smelting in 1797 Portsmouth developed, in just over 10 years, into the major supplier of copper to the entire Navy.

However, another scheme for re-cycling waste metal products[104] was abandoned before it started because of the death of the workman concerned due to "....the pernicious effects of his trade"[105]. His idea was to heat Lead ashes[106] with charcoal in a furnace to recover the Lead metal.

Expansion to both the equipment and the buildings of the Metal Mills was begun within five years of the complex starting work and the reason for some of the earliest changes was the need to make copper bolts as well as sheathing. To save time and effort in changing the plain rolls used for making copper sheathing for the grooved rolls necessary for rolling bolt staves, Goodrich sought and received permission to use the grooved rolls originally intended for working iron[107]. Additional furnaces were erected to ensure there were sufficient quantities of copper for the entire operation[108].

7.6.2. Smiths In addition to the new Smiths' Shop built during the early 1790s, there were further additions to their workspace between December 1808 and February 1812 and again a year later in 1813. The first of these was a workshop with 10 forges for which 35 extra smiths were employed[109], a possible location for this (see Figure 7.4.1) was the shop for repairing Brodies fire stoves - the cooking ranges patented by Captain Brodie and fitted in all warships. The expansion of 1813 was proposed by the Dockyard officers to maintain the balance between the numbers of shipwrights employed and those of the smiths. This was to be achieved by adding a small building to the east of the smiths' coalyard, so the number of small forges would then be increased to 20[110]. As the war drew towards a close, the problem for the Dockyard was not expansion, but that of keeping skilled men employed as the number of ships at sea and therefore the Dockyard workload, declined. By the middle of 1814, they were suggesting that the smiths could re-manufacture old iron into bolt staves and flat iron pieces[111]. Effectively taking on work which had previously been contracted out to Fontley.

Small, more specialized, smiths' shops were equipped to serve particular areas within the Dockyard; one such was for the use of the Millwrights and another produced the iron pins used in the manufacture of the pulley blocks. This was a double forge for which anvils and forging tools were ordered in February 1806 from Maudslay[112], but its delivery in June of that year was not achieved without him being sent a reminder[113].

7.6.3. Foundries. There are a number of references to foundries, but little detail of them is available. Goodrich's Journal records a proposal of 1808[114] to enlarge the existing Brass Foundry increasing its four pot furnaces to eight. The two 16 inch square and one each of 14 and 12 inch square furnaces would be increased to two of 12 inches square and four of 14 inches plus the two existing 16 inch. In 1813 plans were in train for new foundries for working brass and iron, since the Dockyard officers reminded the Navy Board in March of that year that the plans had not arrived and did so again three months later[115]. However Figure 7.4.1 suggests that these had still not been built by 1820.

The Dockyard plans (Figure 7.4.1) show that the Metal Mills went through two stages of development - initially there was a major expansion with the introduction of the full capacity of the copper mills but thereafter there were a series of minor alternations as a result of more ambitious plans being scaled down to a level which maintained the advance of technology without matching the full ambitions of some of the Dockyard officials. The net result is that it is not possible, from the remaining records, to establish the precise nature and timing of the smaller changes in areas like the Millwrights shop - that these facilities were enhanced is indisputable but the extent and degree to which this was achieved before 1816 remains open to question.

7.7 Wood Mills. Table 7.5 summarised the key events in the development of the Wood Mills and it is supported by Figure 7.5 which shows diagrammatically the progress with the development and Figure 7.5.1 sets out to illustrate the various parts of this building which came to house both sawing and blockmaking machinery.

Figure 7.5.1 shows that the Wood Mills initially consisted of two three-storey high buildings with a single storey structure being added later between them. The southern building, in which the ground and first floor appear to have been combined, was situated over the well at the corner of the Reservoir and primarily housed the steam engines and pumps. A drawing of 21 December 1797[116] signed by Bentham shows the sawing machinery sited over the well. However, *Rees Cyclopaedia's* description of the Block Machinery in 1807 locates the sawing machinery on the ground floor of the northern three-storey building so that the shafting from the steam plant must have bridged the ground between the two buildings. Eventually this space was enclosed by the single-storey building and the shafting could then provide power for the block shell machines which were, by then, located in this space.

It is not clear when precisely or why the sawing machinery was moved, but it was undoubtedly still in the southern building in 1801 as a letter of 27 September[117] about the water supply system refers to the "building with two steam engines and machinery...." At that time the steam engines would have been the original 12hp Sadler engine erected in 1798 and a 30hp Boulton and Watt engine installed during 1800-1801[118]. In 1805, when Goodrich suggested the acquisition of a second 30hp steam engine, the costings[119] for the project actually included taking down the 12hp Sadler engine and moving some sawing machinery. It is therefore reasonable to assume that they were moved shortly after this and prior to the installation of the larger steam engine which was supplied in 1806 and came into service in 1807.

TABLE - 7.5

CROSS REFERENCE TO FIGURE 7.1	DATE DAY/MNTH	YEAR	FROM (ORG.)	TO (ORG.)	REFERENCE	SUBJECT MATTER	REMARKS
	NOTE ORGANISATIONS - AB - Admiralty Board, NB - Navy Board, IG - Inspector General of Dockyards. SB- Bentham, SG - Goodrich, MB - Brunel, PD Portsmouth Dockyard Officers						
	BLOCK (MILLS)						
PA1	14-Apr	1802	IGO	AB	ADM 1/3526	Bentham's report on Brunel's proposal for Block machinery	
	11-Jun	1802	IGO	AB	ADM 1/3526	Request for information on Block contracts	Numbers issued to Dkyds in last 5 years
PA2	05-Aug	1802	NB	IGO	ADM 106/2539	Admiralty approval given 2 Aug 1802	Plans recieved, send further info
CN3	04-Oct	1802	NB	IGO	ADM 106/2539	Machinery for 7-10 ins blocks ready in 4-5 months	To be sent to Portsmouth
	21-Oct	1802	IGO	AB	ADM 1/3526	Proposal to buy Dunsterville's machinery	Brunel's machines not ready for four and half months
MN1	05-Jan	1803	NB	IGO	ADM 106/2539	Need for men to operate machines	Admiralty Board approval 4 Jan 1803
	15-Jan	1803	NB	IGO	ADM 106/2539	Parts to be supplied by John Lloyd	For providing power
	01-Mar	1803	IGO	AB	ADM 1/3526	Burr's report from Plymouth	Dunsterville's machine have not been bought yet
ID3	27-May	1803	MB	AB	ADM/Q/3322	Block machines for 7-10 ins completed	Permission needed to proceed with rest of machines
ID2	31-May	1803	IGO	AB	ADM 1/3526	Costs of block machinery and Brunel's share	
MD3	09-Jun	1803	MB	AB	ADM 1/3526	Men needed for running machinery - Burr or Barlow	Burr-Master of W Mills, Barlow to maintain machines
PA5	20-Jun	1803	AB	NB	ADM/Q/3322	Brunel to provide rest of machines	NB note of 24 June - write to Brunel
PN2	25-Jun	1803	NB	IGO	ADM 106/2539	How can they estimate one years savings?	Saving to be paid to Brunel
CN5	26-Jul	1803	NB	IGO	ADM 106/2539	Lloyd's bill - pay when certificate recieved	
CN5	19-Aug	1803	NB	IGO	ADM 106/2539	Bill from John Sherwin, Millwright to be paid	Agreement with Sherwin of 10 Jan 1803
	10-Sep	1803	IGO	AB	ADM 1/3526	Brunel's request for additional advance	Delays due to Brunel's improvements
	29-Oct	1803	AB	NB	ADM/Q/3322	Obtain further supplies of raw materials especially L. Vitae	12 months supplies for 7-10 ins blocks
CN5	17-Nov	1803	IGO	AB	ADM 1/3526	Receipt for £800 signed by Brunel	For work done on block machinery
	19-Nov	1803	IGO	AB	ADM 1/3526	Request for further £1000	£800 already paid
CN1	16-Jan	1804	IGO	AB	ADM 1/3527	Block pins to be bought in from Littlewoods	To check size, workmanship etc
CN3	09-Feb	1804	NB	IGO	ADM 106/2539	Littlewood's pins to be sent to P'mth for assessment	Need to reach agreement for 6 months supply
CN3	14-Feb	1804	NB	IGO	ADM 106/2539	Littlewood to send 4 weekly lots of 1000 pins	In sizes agreed. Land carriage
ID3	03-May	1804	IGO	AB	ADM 1/3527	Balance of costs for first set of machines to be paid	Second set of machines 4-7ins at work (see 15/9/1809)
CN1	31-Aug	1804	IGO	AB	ADM 1/3527	Buy coaks from Maudslay until new Foundry ready	
PN2	03-Oct	1804	NB	IGO	ADM 106/2539	Exact proportions of metals in coaks needed	Needed for contract to supply coaks
	13-Oct	1804	NB	IGO	ADM 106/2539	When will block machinery be ready	Letter from Taylor's re uncertainty of contract length
ID1	25-Oct	1804	NB	IGO	ADM 106/2539	Suspend coak contract with Maudslay	Foundry nearly ready
CN1	07-Nov	1804	NB	IGO	ADM 106/2539	Bentham may employ Coak founder & order supplies	Tools and materials for making coaks
	13-Nov	1804	NB	IGO	ADM 106/2539	Taylor's blockmaking contract to cease in six months	P'mth will be expected to provide all needs
MD4	28-Nov	1804	NB	IGO	ADM 106/2539	Directions given to enter and pay Founder	
PN2	07-Mar	1805	NB	IGO	ADM 106/2539	Is estimate of availability of blocks still correct	See letter of 13 Nov 1804
MD2	24-Mar	1805	IGO	AB	ADM 1/3527	Authority needed to engage workmen	Give warning to Blockmaking contractors
PN2	09-May	1805	NB	IGO	ADM 106/2539	What stock of blocks in store at end of current contract?	
CN1	05-Jun	1805	NB	IGO	ADM 106/2539	Order bellows for block pin forge from Lloyd	
	08-Jun	1805	NB	IGO	ADM 106/2539	Taylor's contract ceased 4 June, all machines still not ready	Penalties of asking Taylor's to continue supplying
	11-Jun	1805	NB	IGO	ADM 106/2539	Blockmakers wares	Account of average consumption
PN2	28-Jun	1805	NB	IGO	ADM 106/2539	Brunel to continue to order machinery	
	16-Sep	1805	SG		Goodrich B10	Unsuccessful trials of Lignum Vitae cross-cutting saw	Altering saw teeth solved problems
PN2	28-Dec	1805	NB	IGO	ADM 106/2539	Can P'mth furnish all block supplies yet?	Need to inform Taylor's re contract
PN2	10-Mar	1806	NB	IGO	ADM 106/2539	When will P'mth be able to supply all blocks and pumps	To meet requirements of whole Navy
CN1	20-Mar	1806	NB	IGO	ADM106/2539	Double forge anvils and tools ordered from Maudslay	Letter from Dkyd officers of 12 Feb 1806
	07-Apr	1806	NB	IGO	ADM 106/2539	Reminder of 12 Feb order to be sent to Maudslay	
PD6	05-May	1806	IGO	AB	ADM1/3527	Reply to Brunel's letter of 13/4/1806 re additional machines	Turning engine, 2 riveting engines for pins, Agreed 6 May

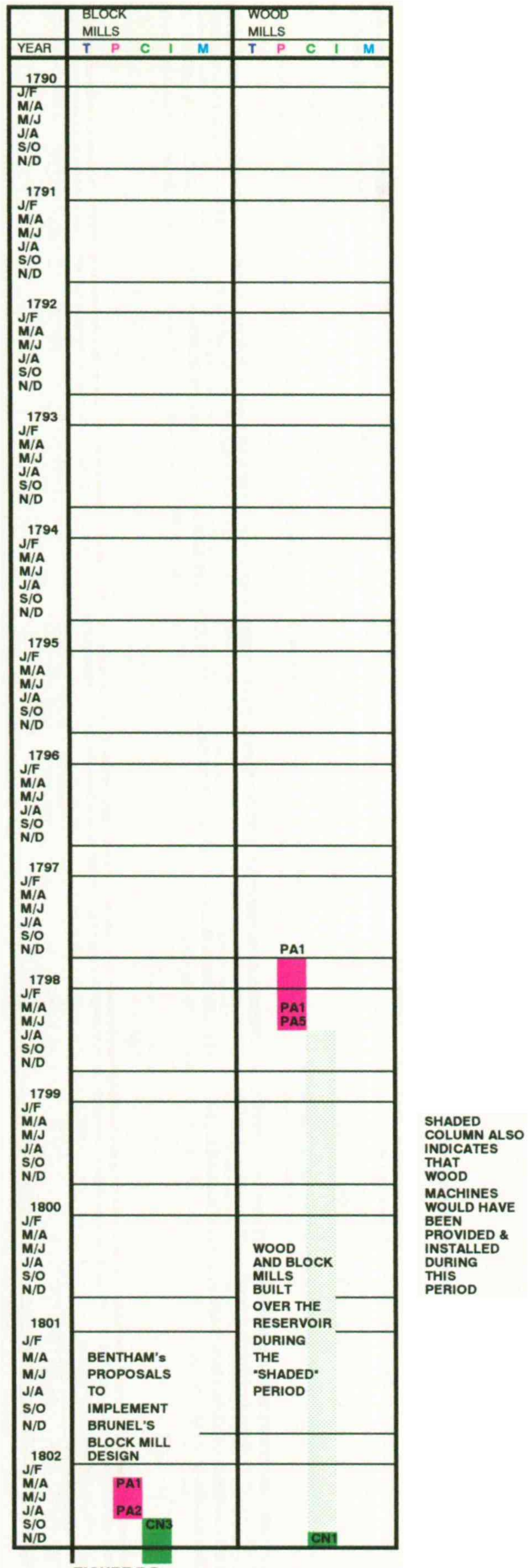

BLOCK MILLS
WOOD MILLS
YEAR
T P C I M
T P C I M
1790
1791
1792
1793
1794
1795
1796
1797
1798
1799
1800
1801
1802
J/F
M/A
M/J
J/A
S/O
N/D
PA1
PA1
PA5
WOOD AND BLOCK MILLS BUILT OVER THE RESERVOIR DURING THE "SHADED" PERIOD
BENTHAM's PROPOSALS TO IMPLEMENT BRUNEL'S BLOCK MILL DESIGN
PA1
PA2
CN3
CN1
SHADED COLUMN ALSO INDICATES THAT WOOD MACHINES WOULD HAVE BEEN PROVIDED & INSTALLED DURING THIS PERIOD

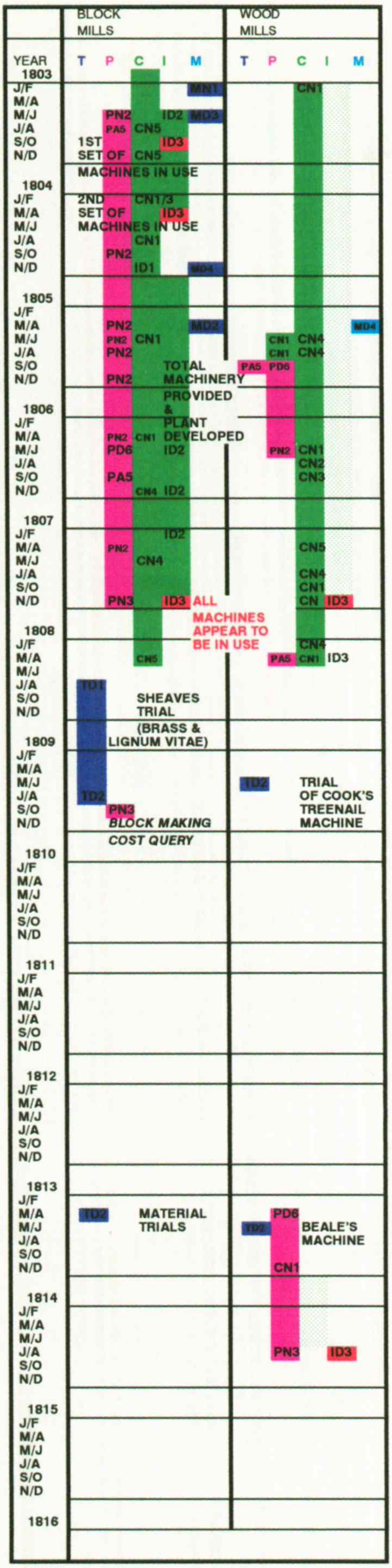
FIGURE 7.5

TABLE - 7.5
CONTINUED

NOTE ORGANISATIONS - AB - Admiralty Board, NB - Navy Board, IG - Inspector General of Dockyards. SB- Bentham, SG - Goodrich, MB - Brunel, PD Portsmouth Dockyard Officers

BLOCK (MILLS) contiued

CROSS REFERENCE TO FIGURE 7.1	DATE DAY/MNTH	DATE YEAR	FROM (ORG.)	TO (ORG.)	REFERENCE	SUBJECT MATTER	REMARKS
ID2	24-Jun	1806	NB	IGO	ADM 106/2539	Inspect Maudslay's bill for anvils and swedging tools	
PA5	24-Sep	1806	NB	IGO	ADM 106/2539	Adlty order of 23/9 for shed for making pumps and large blocks	Estimates and plans to be sent
CN4	17-Nov	1806	NB	IGO	ADM 106/2539	Maudslay's bill for brass coaks for scrutiny	
ID2	05-Dec	1806	NB	IGO	ADM 106/2539	Bill for block machinery from Maudslay sent for scrutiny	
ID2	21-Jan	1807	NB	IGO	ADM 106/2539	Bill for block machinery sent for scrutiny	
PN2	20-Apr	1807	NB	IGO	ADM 106/2539	Is £3470 advanced by Bentham correct?	Bill from Maudslay for scrutiny
CN4	13-May	1807	SG	NB	POR/D/28	Pay for William Barlow for erecting block machinery	
	28-Sep	1807	NB	IGO	ADM 106/2539	Repair for rounding and centering small sheaves machine	Letter to Maudslay of 25 Sept
PN3/ID3	11-Nov	1807	NB	IGO	ADM 106/2539	Confirm that P'mth can now supply items for Blockmaking	Ref to Goodrich letter of 28 Sept to Dkyd officers
	05-Dec	1807	NB	IGO	ADM 106/2539	To report on Taylor's comments on block machinery	
CN5	22-Mar	1808	NB	IGO	ADM 106/2539	Reward to be made to Marc Brunel	Bentham's opinion asked
TD1	09-Aug	1808	PD	NB	POR/D/28	Brass/lignum sheaves for 12ins+ blocks- compare costs	Lignum £50/ton. 120 brass patterns at 21/- needed
TD2	06-Jul	1809	PD	NB	POR/D/28	Estimated use of Lignum for duration by all Dkyds	Reply to letter of 22 June - weight in tons
PN3	15-Sep	1809	PD	NB	POR/D/28	Workmanship & materials expenses against block machinery	From 1 April 1803 to July 1809 by half years
	20-Oct	1809	PD	NB	POR/D/28	Reply to letter of 13 Oct re Blockmakers wages	Workmen pre May 1805, Barlow pre May 1807
	02-Dec	1809	PD	NB	POR/D/28	Survey of Lignum Vitae offered to Royal Navy	
TD2	16-Mar	1813	PD	NB	POR/D/29	Query about use of Teak for block shells	Yellow type more suitable than brown



ADDITIONAL WOOD MACHINES PROVIDED IN THIS PERIOD

ALSO 12 HP SADDLER ENGINE REPLACED BY 30 HP BOULTON & WATT IN 1806/7

PROPOSAL FOR TREE NAIL MACHINERY

SHADED COLUMN INDICATES PERIOD IN WHICH MACHINERY WOULD HAVE BEEN PROVIDED

FIGURE 7.5 (Continued)

TABLE - 7.5
CONTINUED

CROSS REFERENCE TO FIGURE 7.1	DATE DAY/MNTH	YEAR	FROM (ORG.)	TO (ORG.)	REFERENCE	SUBJECT MATTER	REMARKS
	NOTE ORGANISATIONS - AB - Admiralty Board, NB - Navy Board, IG - Inspector General of Dockyards. SB- Bentham, SG - Goodrich, MB - Brunel, PD Portsmouth Dockyard Officers						
	WOOD MILLS						
PA1	21-Dec	1797	IGO	AB	ADM 1/3525	Proposals for machinery to work wood	Reciprocating and rotary
PA1	05-Apr	1798	IGO	AB	ADM 1/3525	Estimated cost of wood machinery and steam engine	Estimated at £1950
PA5	22-May	1798	IGO	AB	ADM 1/3525	Admiralty has agreed to fit machines at Pmth	? extend scheme to Plymouth
	21-Nov	1801	IGO	AB	ADM 1/3526	Inventory of machines & tools at Redbridge	Circular & saw frames, turning lathe
CN1	15-Dec	1802	NB	IGO	ADM 106/2539	Send form of contract to order engine	North building over Reservoir to be completed by Spring
CN1	15-Jan	1803	NB	IGO	ADM 106/2539	Agreement with John Sherwin for shafts and wheels	For saw mills steam engine
PA5	02-Jun	1803	AB	NB	ADM/Q/3322	To order 3 engines for cutting wood	Bentham's letter 1 June. Order from Lloyd
MN1	19-Feb	1805	IGO	AB	ADM/Q/3323	Proposed manning and pay rates for Wood Mills	
MD4	01-Apr	1805			ADM/42/1330/2	James Burr on Paybooks as Master of Wood Mills	
CN1	29-May	1805	NB	IGO	ADM 106/2539	Tools can be ordered immediately	
CN1	29-May	1805	NB	IGO	ADM 106/2539	Request for turning lathe with swivel chuck	Order one for each Dockyard (Letter May 20th)
CN4	30-Jul	1805	IGO	AB	ADM 1/3527	John Lloyd's bill for making & erecting items	Navy Board to pay Admiralty Board note of 3 August
CN1	09-Aug	1805	NB	IGO	ADM 106/2539	Wheel with wooden cogs to be replaced by iron cogs	Accepted and order from John Lloyd
CN1	10-Sep	1805	NB	IGO	ADM 106/2539	Request for lanthorns for Wood Mills	Order 4 dozen from Grimshaw's of Sunderland
PD6	24-Sep	1805	SG	AB	ADM 1/3527	Need to replace Sadler 12hp by larger 30hp engine	Approved 27 Sept and sent to Navy Board
PA5	02-Oct	1805	NB	IGO	ADM 106/2539	Goodrich to prepare drawings for 30hp engine	Originals returned to SG from Adty via Navy Board
	18-Oct	1805	NB	IGO	ADM 106/2539	Send estimates & order cogged wheels from Lloyd	Drawings + list of parts for 30hp engine recieved 12 Oct
CN1	03-Jun	1806	NB	IGO	ADM 106/2539	Additional parts needed for Treenail lathes	Order from Maudslay, see also 4 June 1806 (B14)
PN2	07-Jul	1806	NB	IGO	ADM 106/2539	Are cogged wheels ordered from Lloyd's ready	Steam engine in transit
CN1	12-Jul	1806	NB	IGO	ADM 106/2539	Request for more Lanthorns	Order 6 dozen at the price asked
	19-Jul	1806	NB	IGO	ADM 106/2539	Correction to prices in letter of 12 July	
	22-Jul	1806	SG		Goodrich B14	Lathes on first floor of Pumphouse	Alterations in train. See also 14 June 1806 (B14)
CN2	26-Aug	1806	NB	IGO	ADM 106/2539	Deptford to forward engine boiler	Supplied by Fenton, Murray and Wood of Leeds
CN3	22-Sep	1806	NB	IGO	ADM 106/2539	Grimshaw's have sent 2 dozen lanthorns	To arrive at Portsmouth on Fredrica
CN5	08-Apr	1807	NB	IGO	ADM 106/2539	Pay Grimshaw's bill of £85/18/6	
CN4	09-Jul	1807	NB	IGO	ADM 106/2539	Maudslay's bill for 48 saws delivered to Pmth	
CN4	24-Aug	1807	NB	IGO	ADM 106/2539	Maudslay's bill for circular saws	
CN1	03-Sep	1807	NB	IGO	ADM 106/2539	Additional engines ordered from Maudslay	Letter of 29 August
CN4	23-Dec	1807	NB	IGO	ADM 106/2539	Maudslay's bill for Wood Mills materials & repairs	Sent for scrutiny
CN4	30-Jan	1808	NB	IGO	ADM 106/2539	Bill for Maudslay's men employed in Wood Mills	
CN1	06-Apr	1808	NB	IGO	ADM 106/2539	Machinery ordered from Maudslay	Letter of 4 April
PA5	09-Apr	1808	IGO	AB	ADM 1/3527	Water supply to Wood Mills	See also 12 April 1808
PA5	12-Apr	1808	IGO	AB	ADM 1/3527	Water supply to Wood Mills	See also 9 April 1808
TD2	22-Jun	1809	PD	NB	POR/D/28	Machine for making treenails invented by Mr Cook Shipwt	Very imperfect model and Cook reluctant to lend it
	26-Feb	1811	PD	NB	POR/D/29	Letter of 24 Jan re Pump makers in Wood Mills	Chain pumps always fitted by Shipwrights to continue
	15-Apr	1812	SG		Goodrich B26	Treenail machine proposed by Beale	SG reports to Navy Board on proposal
PD6	07-Apr	1813	PD	NB	POR/D/29	Burr's report on Beale's treenail machine	Principle sound, Beale will make some improvements
TD2	15-May	1813	PD	NB	POR/D/29	Cost of £300, annual saving depends on no of men used	
TD2	15-May	1813	PD	NB	POR/D/29	Burr to send estimates and proposed annual savings	Warrant of 19 April
CN1	23-Dec	1813	PD	NB	POR/D/30	Suggest ordering treenail machine	Need for building and steam engine to run it
PN3	06-Jul	1814	PD	NB	POR/D/30	Reducing men working in Wood Mills	
ID3	17-Aug	1814	PD	NB	POR/D/30	Treenail making machines ready	John Chainey's contract to cease. Employ man for machines

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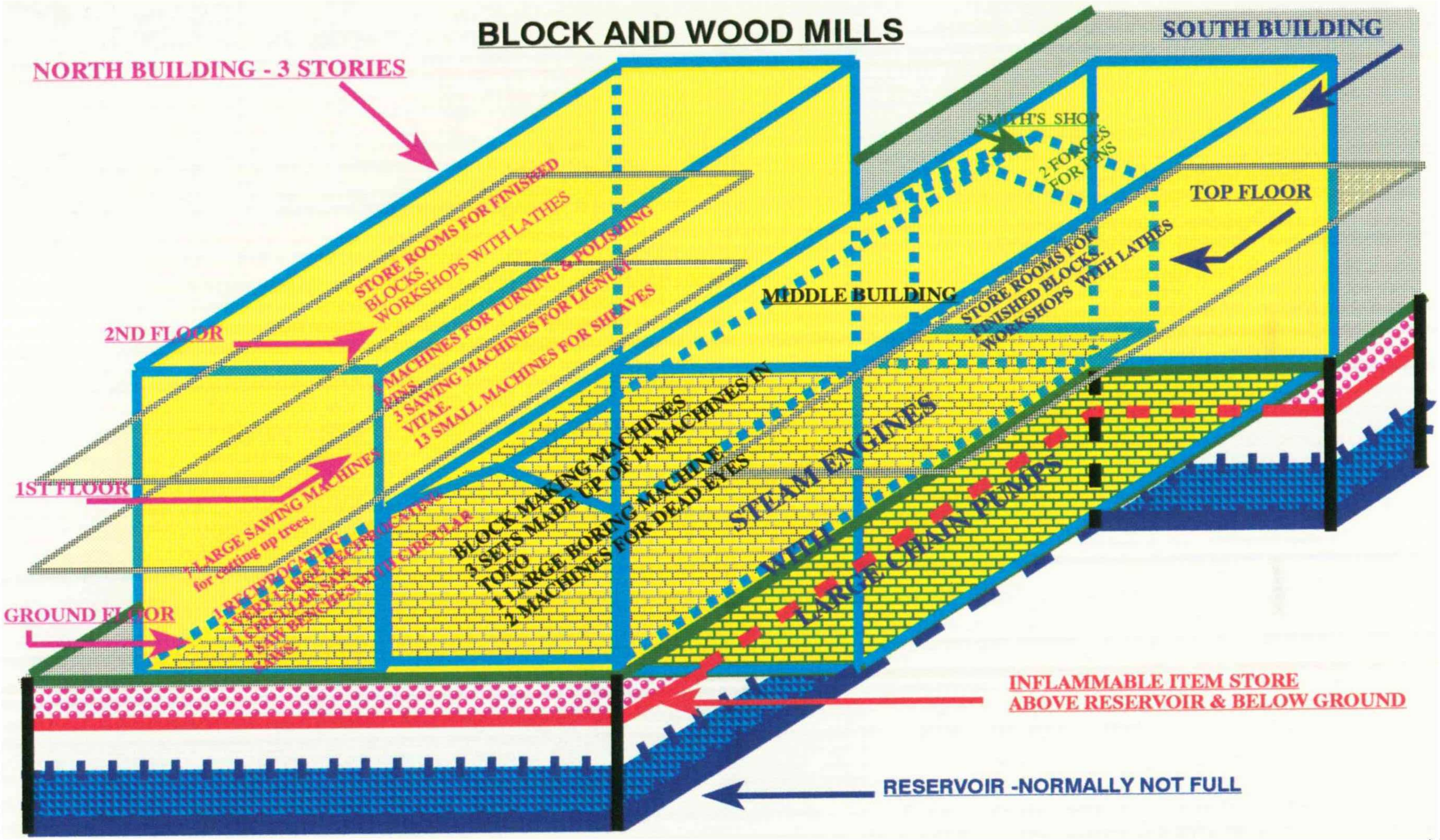

BLOCK AND WOOD MILLS
NORTH BUILDING - 3 STORIES
SOUTH BUILDING
MIDDLE BUILDING
TOP FLOOR
2ND FLOOR
1ST FLOOR
GROUND FLOOR
STORE ROOMS FOR FINISHED BLOCKS. WORKSHOPS WITH LATHES
MACHINES FOR TURNING & POLISHING PINS.
3 SAWING MACHINES FOR LIGNUM VITAE.
13 SMALL MACHINES FOR SHEAVES
7 LARGE SAWING MACHINES for cutting up trees.
1 RECIPROCATING
1 VERY LARGE RECIPROCATING
1 CIRCULAR SAW
3 SAW BENCHES WITH CIRCULAR SAWS.
BLOCK MAKING MACHINES
3 SETS MADE UP OF 14 MACHINES IN TOTO
1 LARGE BORING MACHINE
2 MACHINES FOR DEAD EYES
SMITH'S SHOP
2 FORGES FOR PINS
STORE ROOMS FOR FINISHED BLOCKS. WORKSHOPS WITH LATHES
STEAM ENGINES
WITH
LARGE CHAIN PUMPS
INFLAMMABLE ITEM STORE ABOVE RESERVOIR & BELOW GROUND
RESERVOIR -NORMALLY NOT FULL

FIGURE 7.5.1

7.7.1. Sawing Machines. The initial building was erected to contain sawing machinery first proposed by Bentham and intended for use at Redbridge[120]. Although the Admiralty had shown interest in the machinery, the idea of steam power to drive it had not been accepted and Bentham decided to demonstrate its worth in the manufacture of some ships of his own experimental design[121] but in the event, the ships were completed before the steam engine was delivered. Subsequently Bentham again sought Admiralty Board permission to use the steam engine in Portsmouth Dockyard[122], this time combining its use for driving the sawing machinery with the more urgent need to increase pumping capacity for the enlarged Non-Tidal basin and new Docks. An inventory[123] shows that the machinery at Redbridge consisted of three large and two small sawframes, three large and two small circular saws, a flywheel with stand and a turning lathe and it is a reasonable assumption that some if not all of these machines were moved to Portsmouth for use in the projected Wood Mills.

7.7.2. Blockmaking Machines. Brunel's blockmaking machinery was a revolutionary development in the technology of wood processing. Prior to its invention wood processing machines tended to be single purpose ones which required virtually constant human involvement in their operation and the overall process in which they were involved was still substantially dominated by hand work. However, with his new machines Brunel effectively introduced the "production line" approach in which machine work was the primary process at every stage of the whole and the numbers of a particular type of machine in the plant were varied to ensure a near continuous output of basically finished products from the total plant.

Collectively the blockmaking plant was a system for manufacturing the parts for a pulley block, namely the shell made of elm, the sheave of Lignum Vitae and the iron pin on which the sheave turned. As Rees says, "The whole series are calculated for operating upon large or small work; and this is one of the greatest merits of the machines. More than 100 sizes of sheaves are made by them, of all diameters and all thicknesses."[124] Brunel had designed the machines to ensure that every block part made was identical but the individual machines were sufficiently flexible in operation to be able to produce the range of sizes required. Initially Brunel had been rebuffed by both Taylor and the Admiralty Board when he approached them with his ideas. However, Bentham, who had also been considering blockmaking machinery, persuaded the Admiralty to reconsider Brunel's scheme[125] and Admiralty permission to proceed was given on 2 August 1802[126].

Brunel incorporated in the design of various machines which made up the production line, a range of innovations. Some were simple adaptations of previous inventions whilst others were outright new developments and their importance to the history of technology lies in their collective advance rather than in the individual elements which made up the whole. Since the machines were invented for Portsmouth Dockyard and were developed within it the Yard can justifiably claim to be at least the owner, if not the inventor of this revolution and it is for that reason that the various aspects of the development are now discussed in considerable detail.

7.7.2.1. Construction of the Machines. The plant comprised three similar sets, or production lines, to make 4 to 7 ins, 7 to 10 ins and 10 to 18 ins blocks with either single or multiple sheaves. The machines were built by Maudslay from Brunel's drawings and the principal materials used for their construction were iron with cutting surfaces being made from steel. At that time, many machines still had wooden frames but these lacked the necessary strength and rigidity to withstand the speeds that these new machines were required to work. For example, the chisels in the middle sized mortising machine made 110 strokes per minute[127], hence Maudslay's use of iron frames.

7.7.2.2. Alignment and Accuracy of Marking. Rules and guide rollers were used to achieve the correct shaping of every part which went through the machines. For example, the cornering saw used for the initial shaping sequentially cut a rectangular shape into the oval one of the block shell. To do this the machine had rules set against the ledge to hold the wood in the correct position and height regardless of its length[128]. The guides in the shaping machine had to be even more sophisticated as not all the four surfaces of the block were of the same shape. The front and back of the shell had one curvature, while that of the sides was greater. When the first side was completed, a roller was moved from the first guide to a second and this arrangement gave the correct curvature to both sides. When the process was completed, the roller was returned to the original guide[129].

These machines required the materials being worked on to be held securely in the machines and precisely positioned whilst dust and debris from the process which would have prevented the machines working correctly had to be removed. The necessary positioning of the block shells within their machines was ensured by the fact that the first machine which bored the holes to start the mortises marked the ends of the shells so that they would be held in the correct position in subsequent machines[130]. This attention to controlled and accurate positioning also appears in even the smaller block parts since the site of the holes to be drilled in the metal "coak" were actually marked as part of the casting process.

7.7.2.3. Automation/Semi-unattended Operation. The new machines were amongst the first important examples of automated operations. Here the word 'automation' is used to signify operations preset into the machines and 'semi-unattended operations' for those needing minimal human adjustment, Whilst screw-drives were in use on machines like lathes and pawls and ratchets had been around for many years, Brunel combined these ideas in his mortising machine where the pawl and ratchet controlled the screw thread[131] and thus advanced the carriage holding the block shell by one twenty-fourth of an inch at each chisel stroke[132] without any operator involvement.

7.7.2.4. "On-Line" Power Engagement/Disengagement. Gilbert comments on the innovative nature of the cone clutch used on the mortising machine which enabled the machine to be stopped rapidly and so ensure a uniform length to the mortises[133]. Other machines could, by the use of "blind" pulleys, be disconnected from the power source without stopping the flywheel. This was achieved by moving the belt across the pulley which had been driving the machine to a second "idler" pulley which was free to rotate independently of the drive shaft passing through it[134].

7.7.2.5. Variable speed and Power of Operation. Some machines could also work at different speeds depending upon the work being done. In the face-turning lathe used in the manufacture of the sheave, the machine has to turn both the metal coak which has already been inserted into the wood and the wood of the sheave. Rees describes the process...."Thus, when the machine is first set in motion, and as long as the tool continues turning the bell-metal, the strap is upon the slow pulley; but as soon as the workman sees the tool is beginning to cut the wood, he shifts the strap upon the quick pulley, by which its velocity and consequently that of the lathe, is immediately doubled, and continues so until the sheave is finished turning; and then the workman returns it back again to the slow pulley, and immediately after shifts the strap to the idle pulley upon the spindle A, which slips round upon it and the motion ceases."[135]

7.7.2.6. Simultaneous multi-operations. The crown saw was used to make the sheave circular whilst simultaneously a hole was drilled through the centre of the sheave. To achieve this the saw and the drill had to operate at different speeds. This was effected by the saw and the drill each being driven by separate pulleys running at different speeds, the pulley for the saw being larger than that for the drill[136].

7.7.2.7. Cooling and Lubrication. With the machines for turning and polishing the pins Brunel had to make provision for cooling the fast moving parts. The turning machine was similar to a lathe, but with a triangular rather than circular bar[137] so that when water was used to cool the turning tool, it fell past a flat side on the triangle (and since it did not wet the bar that did not rust). The water coolant was supplied from a small vessel with a cock ".... set to drop a small stream of cold water on the tool to keep it cool; but the water falls together with the shavings, clear down through the iron frame, and is caught in the cistern below."[138]

To polish the pins, they were drawn through steel dies fixed in a box which contained oil to prevent the heat created by the effect of friction from damaging either the pin or dies. Two pans connected to the die box received the oil displaced by the passage of the pin through the dies so that the necessary oil level could be maintained[139].

7.7.2.8. Waste product Re-cycling. In the Pin turning machine the metal swarf from the pins was collected in a cistern with the water and was then recovered by filtering off the water prior to re-cycling. The metal turnings from the face turning lathe were also recovered and returned to the foundry for re-use. Rees describes the process ".....The turning dust which this machine makes, is winnowed in a machine, similar to that used in corn-mills, to separate the wood-chips from the metal-turnings, which are returned to the foundry to be re-melted and used in casting other coaks."[140]

7.7.2.9. Safety. Modern photographs[141] of the circular saws, which survived until quite recently, show them with guards although these do not appear on the early/original drawings of the machines and thus they may well be later additions to conform with safety requirements. The shaping engine, however, was fitted with a guard as part of the original design[142] although its effectiveness is open to question in the light of an unattributable report on an accident with the machine "....The accident alluded to was occasioned by one of the wheels of the chuck cracking in the rim, so as to let loose the blocks, and they all flew out behind the machine, passing through a window, into the steam-engine house, where they struck the governor or regulating balls of it, and broke them in pieces. It is singular that, in passing through the window, all the blocks followed each other through the same pane of glass with great violence."[143]

Initially the metal parts of the blocks, the coak/bush and the pin, were obtained from outside sources since the Dockyard was not equipped to produce them. The coaks were made by Maudslay's works for a period of several months from September 1804[144] but later in that year, Bentham was given authority to employ a Founder and purchase the necessary tools and materials[145]. Pins were provided by Littlewood's foundry but eventually a double forge manned by two smiths forged the iron pins within the Wood Mills.

The Navy Board had earlier informed the Inspector General's office that the first set of block machines, to make the 7 to 10 ins blocks, should be ready in February 1803[146]. In fact, they did not begin producing blocks until September of that year[147] and it was May 1804[148] before the second set (4 to 7 ins) was also on line. More significantly, it was to be November 1807 before the whole system was completed and in operation[149]. The delays were in part due to improvements by Brunel - for example, the first shaping machine required a quarter turn by the workman to shape each side whilst in the later versions this process was automated[150]. Secondly there were outright additions, for instance, two riveting machines were added. Although it has been suggested that the idea for these came from Bentham[151] as he felt Brunel's idea of rivetting the coaks by hand was too inaccurate. Another addition in April 1806 was a machine to turn iron pins up to five inches diameter and thirty inches in length for the large blocks since the machine already installed was too small[152].

Although the design of the plant machinery was Brunel's, it had been intended from the start that there should be a close working relationship between Brunel, Bentham, Goodrich and Maudslay[153] and the Portsmouth plant undoubtedly owes much to this co-operation. Once Brunel had made all the alterations he considered necessary to ensure the smooth operation of his system, there were no further additions and alterations. Indeed it ran as a complete system and provided pulley blocks for the Royal Navy until metal ships superseded wooden ones, and block production actually only finally ceased in the 1960's[154].

The determination of the output of the Wood Mills, its productivity and the extent to which the plant was mechanised as a whole can be assessed with only varying degrees of accuracy due to gaps in the records available. Whilst the works of Carolyn Cooper and K.R.Gilbert described the block machines, neither addressed the level of hand work which would have been necessary, for example the finishing and assembly of the blocks. Nor did they consider the ancillary tasks needed to support the plant as a whole and neither offers precise figures on the total manning level for the machines. However Rees is more specific in relation to the block machines, and says that four men worked the shell making machines and six were employed on the machines making sheaves[155] but this was only in relation to one set or production line. Brunel's notebook quoted by Cooper[156] gives design production data for an eleven and a half hour shift and states that when working the block shell machines, one man operated the mortising and boring machines and one man also operated the shaping machine and scored the groove around the shell. However there is no corresponding data concerning the other machines for making the sheaves or pins.

Fortunately the manning levels of the Wood Mills as a whole are available from the paybooks and these are included in Table 5.4 in Chapter 5. However the question then arises of whether the mills did or did not work more than one shift daily and here again there is no precise information available. Nevertheless, it is reasonable to suggest that only one shift was worked per day because Bentham's design philosophy was that the power from the steam engines should be used at night for pumping out the reservoir and dry docks. This is reinforced by Goodrich, who in 1805, when putting forward the case to replace the 12hp Sadler engine (the smaller of the two engines on site, the other being 30hp) states that there was insufficient power for the Wood Mills. This implies that there was no pumping capacity whilst the mill was working which would have meant that all pumping was indeed done at night and therefore the mills only worked a single shift. Taking all this into account, it is possible to arrive at a reasonable assessment of how the total Wood Mill workforce could have been employed, based on three assumptions. Firstly, that the manning practises for the block machines were also applied to the others. Secondly, an allowance is made for hand assembly work and thirdly, provision is made for unavoidable support tasks. The outcome is shown in Table 7.5.1.

NOTES FOR TABLE 7.5.1

Ref	Comment
A	Assessed at one man per machine.
B	It has been assumed that there are 3 scoring machines, one per set although K.R.Gilbert shows only 2. (Gilbert, The Portsmouth Blockmaking Machinery page 9)
C	Assessed at one man per machine.
D	Assessed at one man per machine.
E	Assumed that whisket for wooden pins wasn't in use all the time.
F	Assessed at two men for each set of block machines.
G	Assessed at one man per machine.
H	Assessed at one man per machine.
J	Rees Naval Architecture says that lathes were used to make dowels, treenails, marline spikes, pump parts, capstan bars etc. The evidence suggests that there were at least 8 lathes. (Rees Naval Architecture page 166)
K	Assessed at one man per machine.
M	Known to exist from Paybooks, correspondence etc.
N	Assessed as one foreman for the block mills, one for the wood mills and one cabin keeper (kept and issued the "ready use" tools and "consumable stores etc.)
P	Assessed as necessary to handle output sent to Fleet and Dockyards.
Q	Assessed at one man per floor. But would have been assisted by the "boys"
R	Assessed as necessary to receive materials for Wood Mills.
S	Assessed as one for each floor with machines to remove rubbish and fire hazards.
T	Based on Bentham's proposed manning and seen as necessary to assist machine operator with large and heavy items - not forgetting that the largest machines could cut up a full sized tree trunk.
U	Based on Bentham's proposed manning which included 10 "boys". Interestingly, this equates to 10% of the total manpower of Wood Mills. Indeed anything less than 5% for training and 5% for sickness/absence etc. would seem close to being unrealistic.
V	Based on Bentham's proposed manning.
W	Based on Bentham's proposed manning.
	NOT INCLUDED IN LIST
1	2 Smiths making pins. Probably paid under Smiths.
3	Watchmen. Employed for Dockyard as a whole (see Dockyard Paybooks)
4	Clerks/Storekeepers - Accounting Staff not included in Wood Mills pay books.

TABLE 7.5.1
WOOD AND BLOCK MILLS - MACHINERY AND PERSONNEL POPULATIONS

PART OF THE MILLS	PLANT/SUB-AREA MACHINE / *HAND*	TOTAL NO. OF MACHINES	NOs OF MACHINES PER SET/PROD. LINE (BLOCKS ONLY)	MANNING OF MACHINES: OPERATOR	MANNING OF MACHINES: SUPPORT	MANNING OF NON-MACHINE ACTIVITIES	NOTE REF.
BLOCKS	**SHELLS**						
	BORING	3	1				
	MORTISING	3	1				
	CORNER SAW	3	1	15			A
	SHAPING	3	1				B
	SCORING	2	2 BETWEEN 3				
	SHEAVES						
	SAW- RECIPROCATING	1	1 BETWEEN 3				
	SAW CIRCULAR	2	2 BETWEEN 3				
	SAW-CROWN/TREPAN	2	2 BETWEEN 3				
	COAKING	2	2 BETWEEN 3	16			C
	DRILLING	1	1 BETWEEN 3				
	RIVETTING HAMMER	2	2 BETWEEN 3				
	BROACHING	3	1				
	FACE TURNING LATHE	3	1				
	PINS						
	TURNING LATHE	3					
	POLISHING MACHINE	1	1 BETWEEN 3				
	WHISKET	1	1 BETWEEN 3				
	(LATHE FOR WOODEN			3			D
	PINS						E
	HAND ASSEMBLY OF BLOCKS					6	K
WOOD	**MISCELLANEOUS**						
	BORING MACHINE FOR	1		1			F
	V.LARGE BLOCKS						
	DEAD EYE MAKING	2		2			G
	WOOD TURNING LATHES	8		8			L
	WOOD SAWING						
	RECIPROCATING	1					
	CIRCULAR	1		7			H
	V.LARGE RECIPROCATING	1					
	SAW BENCHES	4					
	MASTER OF WOOD MILLS					1	M
	FOREMEN & CABIN KEEPER					3	N
SUPPORT ACTIV TIES	*Raw material receipt*					2	P
	Transfer of Material around Mill					5	Q
	Finished Products - out					2	R
	Cleaning					5	S
	Wood handlers for saws				12		T
	TRAINEES BOYS					10	U
	ENGINE KEEPERS					2	V
	MACHINE REPAIRERS					2	W
	(TOTAL NUMBER MACHINES)	(53)					
TOTALS	TOTAL- MACHINE OP			52			
	TOTAL MANUAL -MACHINE SUPPORT				12		
	TOTAL MANUAL SUPPORT					38	
	GRAND TOTAL MANNING			GRAND TOTAL 102			
	1808 - ON PAYBOOKS			102			

Sadly the available records do not contain details of the output but it is known that the fleet used 154285 new blocks in 1806[157] and at that time all new blocks were coming from Portsmouth. From this and Table 7.5.1 it is possible to generate some indications of the wood and block mills productivity. Firstly, it would seem reasonable to suggest that block mill was producing an average 498 blocks per day, or 43 per hour over an eleven and a half hour working day at just over one man-hour per block. Perhaps even more interesting is that only 6 men out of the forty involved in blockmaking were engaged in hand work. Across the mill as a whole it is assessed that 53 machines were manned and directly supported by only 64 men. However those 64 needed to be backed up by a further 38 to run the Mill as a whole.

There is no direct evidence to support the precise assessment shown in Table 5.7.1 of how all these 38 men were employed. However, bearing in mind that the mill had five working floors, on three different levels, and that a very large amount of raw material was moving into it every day whilst large quantities of both processed wood and waste material were constantly having to be moved out, the illustrative allocations look very reasonable - especially when Bentham's proposals for training (boys), machinery repair and engine keepers are added in[158]. Certainly the block machinery design and the basic arrangements for the Mill must have been sound since the block mills remained in operation for over 150 years - a great tribute to its designers. Nevertheless it took much longer to bring the mills "on line" than the Admiralty had expected and had originally planned on.

The period 1803 - 1807 was a particularly difficult period in the history of the Portsmouth Wood Mills. Not surprisingly, having invested considerably in this major plant the Navy Board was soon trying to terminate its contracts for blocks with contractors. At the same time, the needs of the fleet dictated that supplies had to be maintained regardless of problems with their manufacture. Therefore the delays mentioned earlier were a source of considerable all round annoyance and exasperation. For three years, the Navy Board had to deal with uncertainties in the supply of pulley blocks not just for Portsmouth, but for the entire Navy with the additional problems of having to negotiate a series of small scale contracts with their original suppliers. Taylors, the largest of the block making contractors could especially feel aggrieved at having had their major contract cancelled and then being almost coerced into continuing to supply the Admiralty without a long-term market for their products.

There are a series of letters from the Navy Board to the Inspector General's office between October 1804 and November 1807[159] requesting information on when the block machinery would be fully working. An example is a letter of 13 November 1804; "We received your Letter of 1st inst and have given Messrs Taylor to understand that we shall continue to demand of them for six months to come such articles included in the contract of Blockmakers Goods as may be wanted according to the common usage of the Service. And acquaint you that at the expiration of that time we shall expect the supply of all the said articles for the service of the Navy to be furnished from the machinery erected in Portsmouth Yard."

The six months ended in May 1805, and in June when Taylor's contract had - with Admiralty Board approval[160]- been stopped, the Navy Board to their annoyance were told that only blocks of sizes "....up to 10 ins could be made until 1st August next"[161]. This meant that Taylor had yet again to be asked to continue to supply and of course he was then very much able to make such terms as he pleased. It would be another eighteen months before the Navy Board were asking Goodrich to confirm his statement of 28 September 1807 that"....the Wood Mills would be able to make and furnish by the 1st inst all the articles mentioned in the Blockmakers contracts except those which you have pointed out."[162]

The eventual success of the block machines in producing very large quantities of uniform items may have predisposed the Dockyard to consider the possibilities of making other large quantity items with specialist machines and one such idea was a machine to make treenails. In 1809, the Dockyard officers examined a machine invented by a shipwright named Cook[163], but dismissed the idea as impracticable. In 1813 a much better one-man operated[164] invention by Mr Beale was examined by James Burr, the Master of the Wood Mills. In the interests of accuracy, he suggested that the machine parts, whether wholly or partially made of metal, should be made in London under Beale's supervision. This would have followed therefore the example of Brunel's metal framed, steam driven machines with which Burr was very familiar. No details of Beale's machine exist, but he made a number of adjustments to his original design at Burr's request[165]. Nevertheless, there remained the problem that there was no spare power capacity available from the Wood Mills steam engines and to overcome this Burr cleverly suggested the purchase of a 6hp engine[166]. The treenail machine would only need about 2-3hp so the remaining horsepower could be used for boring pumps - a job still being done by manual power. The purchase of the steam powered machine was approved and it was ready for operation by August 1814[167], at which point the contract with John Chainey who had made treenails in Portsmouth Dockyard since 1773 was terminated.

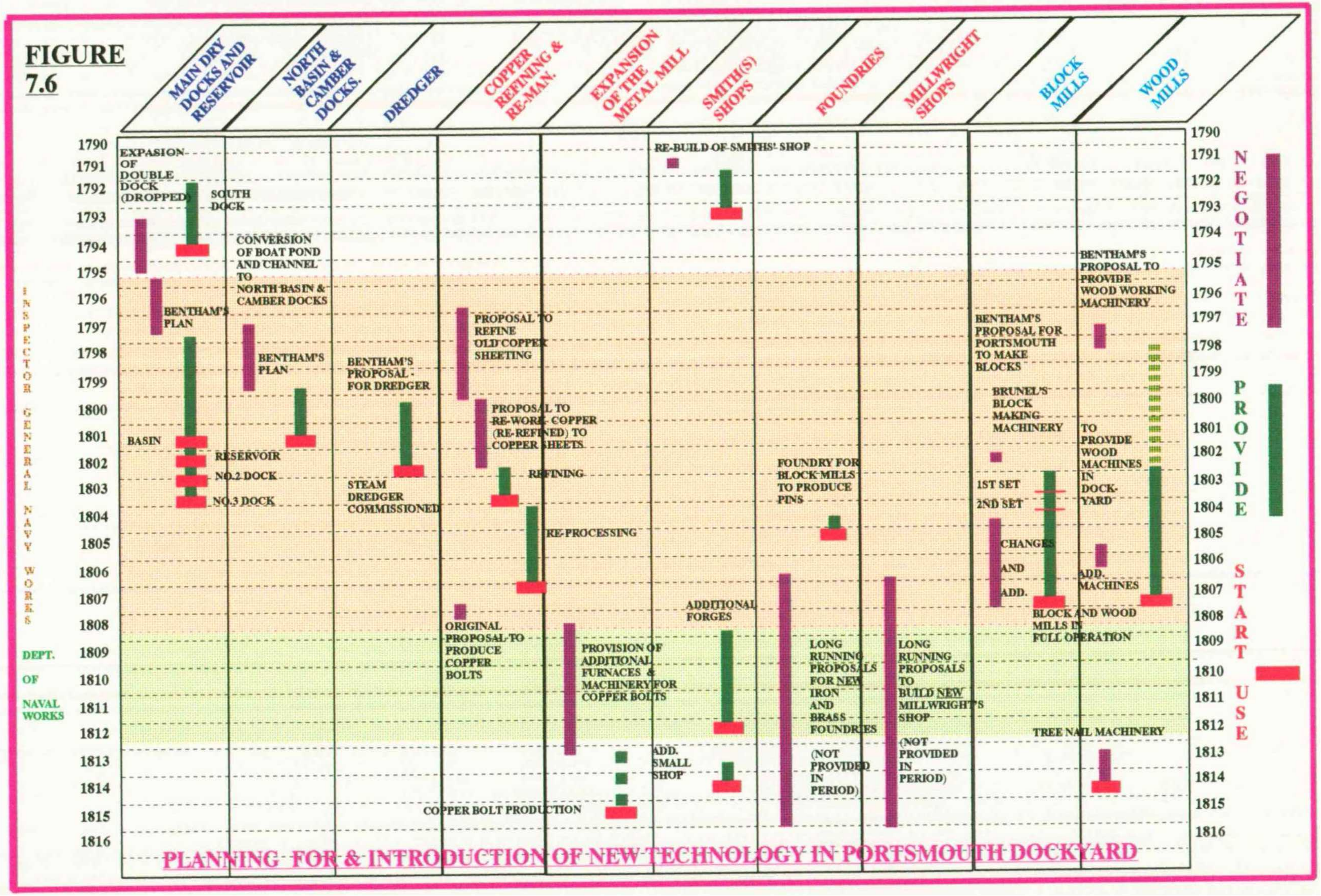
This contract cancellation, coming on top of those for the commercial block makers, and indeed the copper processing plant provides the likely answer to a question raised earlier of why the Dockyard workforce apparently never objected to the introduction of new technologies. The penalties in terms of loss of employment arising from the new machines fell not within the Dockyard but on contractors outside. Beamish in his biography of Brunel[168] says that "TEN MEN, by the aid of this machinery, can accomplish with uniformity, celerity and ease, what formerly required the uncertain labour of ONE HUNDRED AND TEN."

If that was the case then the men put out of work by the Portsmouth Blockmaking machinery were those employed by Taylor in Southampton and the other blockmaking contractors - not men in the Royal Dockyards.

<u>7.8 Overview of the Application of New Technologies in Portsmouth Dockyard</u>. Figure 7.6 brings together the technical advances and applications discussed in this Chapter and it does this against the background of the Admiralty and Navy Boards' organisation for managing the development of the Royal Dockyards in the period. Figure 7.6 is supported by Figure 7.2 which summarises the growth in Portsmouth Dockyard of the use of steam power.

1799 saw the introduction of the Dockyard's first steam engine which was a 12hp Sadler table engine used to power the wood cutting machines by day and pump out the Reservoir by night. Over the next 8 years, the total horsepower used in the Yard rose steadily to 146hp. 66hp of this was involved with powering the Wood Mills in association with the Reservoir, 62hp was used in the Metal Mills, 12hp in the Steam Dredger and only 6hp was used as a general alternative to horse/manpower for such tasks as pile driving and operating cranes etc. After 1807, two more small machines were introduced but again they were for use in continuous, factory-type operations. The strong deduction to be drawn from Figure 7.2 is that steam power was only introduced where there were clear operational or economic benefits from so doing and that these circumstances were predominantly confined to those installations which operated continuously, and on fixed sites. Only the cases for introducing the dredger and the mobile engine involved what might be called horse/manpower substitution.

FIGURE 7.6



PLANNING FOR & INTRODUCTION OF NEW TECHNOLOGY IN PORTSMOUTH DOCKYARD

The first major work area to benefit from technological investment was the Dry Dock Complex and this investment had three facets; highly imaginative and innovative management, outright new developments; such as Caissons and a steam powered dredger, and shared exploitation of steam power with the Block and Wood Mill. As the table on Figure 7.3 shows there were around 1,800 theoretical dock days available per year in 1791 at Portsmouth but by 1803, following the improvements, this had risen to close on 3,000. The significance of this becomes apparent when it is appreciated that from 1804 until 1815 the annual utilisation rate (Figure 7.3) rose steadily from about 2,000 to a peak of just under 3,000 in 1814.

The Metal Mills represent the second major investment area with the prime focus being on the recovery and reprocessing of the copper sheeting regularly removed from, and replaced, on ships hulls. In this area the technology was already relatively mature in the commercial field but the Navy Board was constantly worried about the regularity of supply and variabilities in quality. What would today be called the Feasibility and Definition phases of the Project to establish the requisite plant in Portsmouth Dockyard took some six years largely due to uncertainties in the original specification and subsequent major changes as time went by. In the event the plant was in full production by 1807. At which time, it was assessed as being able to meet 66% of the then current total annual Naval requirement for 1172 tons of sheet and 514 tons of copper bolts. Thus going a long way towards meeting the Admiralty's requirements for security of supply and assurance of quality, as well as providing undoubted economies. Perhaps the most significant feature of the Metal Mills was that they, in conjunction with the arrival of steam engines, provided the platform for the development of sheet metalworking, foundry work and engine/boiler installations and repairs just a decade or two before steam power and iron hulls started to replace sail and wooden hulls in new construction warships. Whilst these forthcoming "Revolutions" in warship design were not yet recognised there is no doubt that the instigation of new metal crafts and trades such as the Engine Keepers and Millwrights, together with the establishment of the post of Mechanist and Engineer on the Navy Board provided the startpoint for the new expertise that would soon be vital for the Navy.

The last major area to benefit from new technology was woodworking. Here the technology introduced was very much at the leading edge of powered machine development and was even more advanced in terms of the deployment and operation of individual machines as a co-ordinated production facility. In the case of blockmaking, some 51 machines and only 57 men were capable, once the plant was in full production, of meeting the full annual naval requirement for blocks of all sizes which was assessed in 1807 as being 154,285. Although it took from 1802 to 1807 to bring the plant into full production, some years later than the Navy Board had planned on, the machinery was so successful that it remained in use until the 1960s. A real tribute to its inventor - Marc Brunel.

All these advances took place in the relatively short space of 18 years and all were master minded by Samuel Bentham and a small team of fewer than 15 men. The Navy was indeed extremely fortunate to have been able to bring together such a team at a critical point in its history and it is little short of amazing that it managed to retain Bentham's services and his loyalty throughout. It can be said with considerable certainty that in Bentham, his team and the relevant parts of Portsmouth Dockyard Management, the Navy was served with skill, success and dedication.

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4. Ibid, pp.265-266.

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10. ADM/Q/3320, Note on a letter of 4 November 1799.

11. ADM 1/3527, Letter of 24 September 1805.

12. ADM 106/2539, Letter of 19 December 1805.

13. ADM 106/2539, Letter of 26 November 1805.

14. ADM 106/2539, Letter of 14 November 1805.

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23. POR/D/29, Letter of 1 March 1813.

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38. POR/D/27, Letter of 18 March 1796.

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40. POR/D/27, Letter of 31 August 1797.

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CHAPTER EIGHT
CONCLUSIONS

The period 1790 - 1815 is rich in the history of both the operations of the Royal Navy and the Development of Technology, yet relatively little is recorded on how the British Fleet was maintained on near continuous operations for over twenty years and what part the new technologies played in that vital support task.

This Thesis addresses part of this perceived historical vacuum by assessing the work undertaken in the largest of the Royal Dockyards at Portsmouth, examining the new technologies which had potential relevance to that work and considering the benefits arising from those technologies which were introduced whilst also discussing the reasons, known or surmised, why others were ignored or rejected. Statistics have been assembled in both graphical and tabular form to show how the Dockyard's output and productivity grew in response to the demands made on them and how also the Dockyard workforce developed in parallel. Tables and charts also have been introduced to illustrate the rate of progress with the introduction of new technologies into that Dockyard.

The impetus for the introduction of new technology did not arise from within the established organisation of either the Admiralty or Navy Boards but rather from the unique organisation of the Office of Inspector General of Naval Works. This was created as an adjunct to the Admiralty Board in 1795, transferred to the Navy Board as the Department of Naval Works in 1808 and finally abolished in 1812. Interestingly, its principal, Sir Samuel Bentham, whose background and activities in these timescales were discussed in Chapters Two and Seven, owed his appointment to the power of patronage that dominated government service at that time rather than to any previous employment in the business of the Royal Navy. Yet to him must go much of the credit for the advances in technology in Portsmouth.

The Government's requirements from the Navy altered significantly during the war; initially its aim was to isolate Great Britain, its friends, its territories and possessions from the "evil" influence of the French Revolution. In the first years of the nineteenth century the immediate priority was to prevent an invasion of this country and when that threat was effectively defeated by the British victory at the Battle of Trafalgar in 1805 the protection of the country's overseas trade had become absolutely fundamental to financial survival and the eventual defeat of Napoleon. By 1810, after many years of vacillation, the Government had arrived at a realistic strategy for the use of its land forces but the success of those forces overseas was heavily dependent on supply and reinforcement from Great Britain.

Thus the Royal Navy was called upon to escort convoys supporting Wellington's growing Peninsular Army from British ports; across the whole Atlantic coast frontage of the French Navy (and its privateer compatriots) to destinations in Portugal, Spain, and eventually Southern France - whilst at the same time continuing its worldwide protection of British trade and possessions.

To meet these requirements successive British Governments, to their credit, accepted the need, even during periods of severe financial difficulties, to fund a steadily increasing Fleet, but as the objectives of the war changed so also did the composition of the Fleet. As Figure 3.8 showed there were around 160 ships of the line and 230 smaller vessels in 1790 but this grew to 211 and 768 respectively by 1809. Nevertheless, as Figure 8.1 indicates, the number of line of battle ships at sea remained relatively constant throughout the whole period and the real operational growth occurred among the smaller vessels. In the same period between a third and a quarter of the total fleet was generally in dockyard hands at any one time - either in reserve, awaiting disposal, or refitting to make good the wear and tear inflicted by the forces of nature which did far more damage to the Fleet than the enemy did! At its extreme the severity of this damage was illustrated in Figure 3.9 which showed the numbers of ships lost each year due to various causes - of no fewer than 482 ships lost during the war (39 in 1807 alone), 326 were either wrecked on shore or sank at sea. Only 125 vessels were captured by the enemy and just 16 British ships were destroyed in action. Between 1790 and 1815 there were over eighteen hundred entries of ships in Portsmouth Dockyard and the records show that the greatest proportion of remedial work undertaken on the vessels was due to environmental, rather than enemy, causes. Moreover, these records make the point that without the sustained and effective support of the refitting dockyards the Fleet would never have been maintained in the state of repair needed to achieve the eventual successes it did.

Early in the war the Admiralty accepted that to maximise the operational fleet at sea there would have to be increasing reliance on private commercial sources for new ships whilst the major Royal Dockyards concentrated more on refitting. This was particularly true at Portsmouth, which was the Navy's biggest refitting yard and undertook some 30 - 40% of the total annual Naval refitting work. This consisted primarily of repairing and replacing worn out material and "making good" leaks which tended to become progressively worse in hard-worked ships with the passage of time since their last refit. The records of ships worked on at Portsmouth mentioned earlier also provides the material for an indicative measurement of the Yard's year by year "output", in terms of tons/dock/days and Figure 4.13 illustrated how this rose from around 2 million at the start of the period to 4 million at the end.

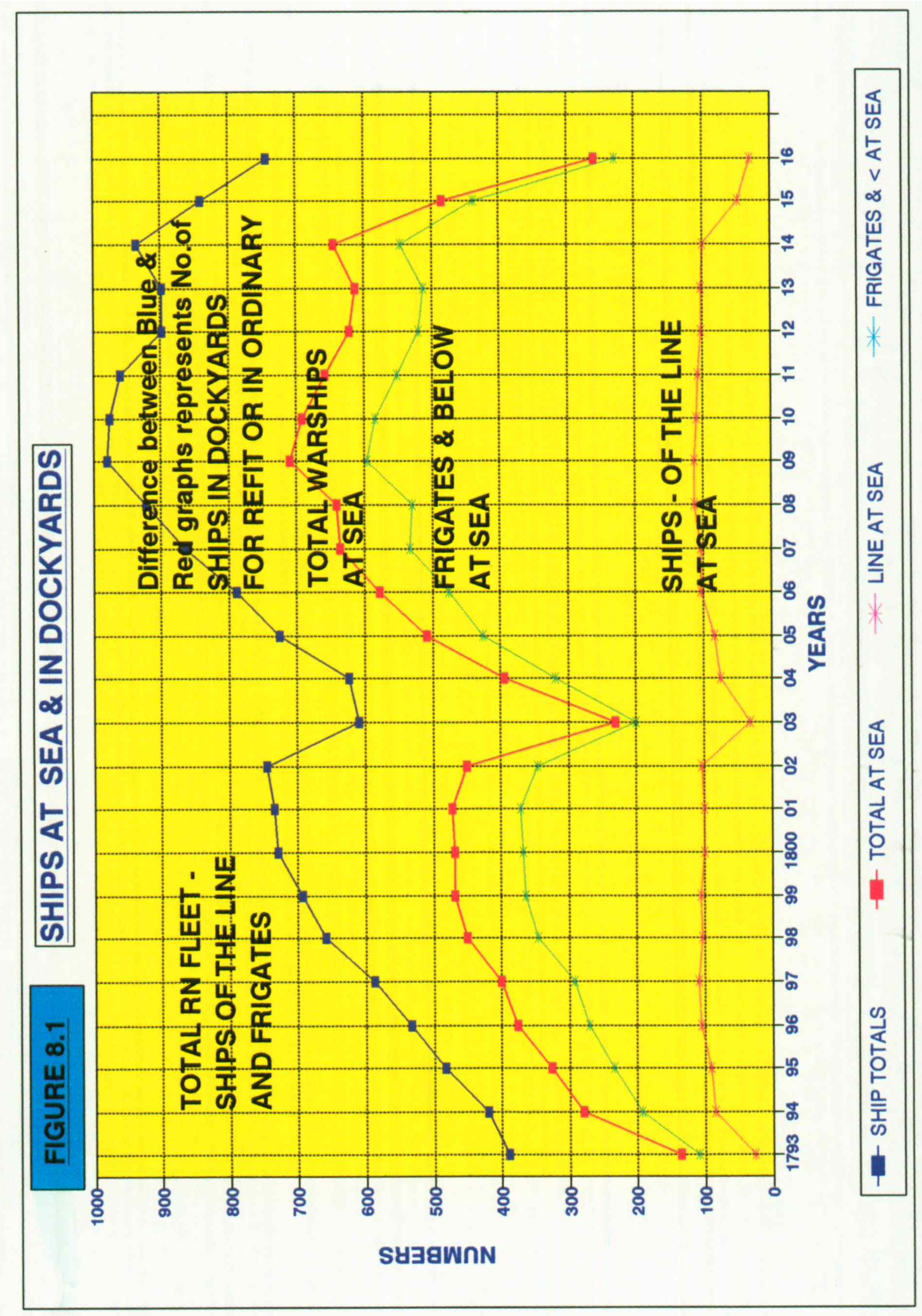


FIGURE 8.1
SHIPS AT SEA & IN DOCKYARDS
TOTAL RN FLEET - SHIPS OF THE LINE AND FRIGATES
Difference between Blue & Red graphs represents No.of SHIPS IN DOCKYARDS FOR REFIT OR IN ORDINARY
TOTAL WARSHIPS AT SEA
FRIGATES & BELOW AT SEA
SHIPS - OF THE LINE AT SEA
NUMBERS
0
100
200
300
400
500
600
700
800
900
1000
YEARS
1793
94
95
96
97
98
99
1800
01
02
03
04
05
06
07
08
09
10
11
12
13
14
15
16
SHIP TOTALS
TOTAL AT SEA
LINE AT SEA
FRIGATES & < AT SEA

However the figures are distorted at the start and end of the period, due to two very large ships which occupied dry docks for a number of years during which little work was done on them. Once these distortions are removed from the calculations a realistic indication of the increase emerges at around 107% over the period 1793-1815. The peak in 1803/4 could be explained by the need to rapidly re-activate the Fleet after the Peace of Amiens whilst that in 1806 might well have been, in part at least, consequential on the Battle of Trafalgar.

As a broad generalisation much of the refitting, and indeed fitting out, work had to be undertaken "in situ" on the ships concerned; often in small confined spaces or with the workmen precariously positioned on staging over the ship's side or up amongst the rigging. Consequently the emerging new technologies, which invariably involved fixed installation machinery, offered no substitute for the use of manual skills and tools. Indeed it could be said that the Napoleonic War, which was the last major war involving all wooden ships, saw the finest, as well as the final, flowering of the shipwright's craft.

Of all the resources used in the Royal Dockyards, the biggest was inevitably manpower and whilst the Navy Board had been attentive in the last decade of the 18th century to the need to invest in increased output from Portsmouth and the other dockyards, it had singularly failed to address how it could sustain and expand its Dockyard workforce. As a result, by 1803 there was severe undermanning due to the workforce being very seriously underpaid compared to their commercial counterparts. Thus, at the time when the new technologies were first introduced into Portsmouth, the attention of the workers was primarily focused on attaining a reasonable wage level and the new technologies were not seen as an immediate threat to their livelihood. It seems fair to conclude therefore that Portsmouth Dockyard, unlike many other major industrial sites in the country during the Industrial Revolution, did not have to contend with serious opposition to new technologies from its workforce. Undoubtedly there were job losses; particularly in the blockmaking and copper processing areas but they fell upon the erstwhile Navy contractors' workforces. Indeed, as Figure 5.6 showed the dockyard labour force eventually grew from 2,394 in 1790 to a peak of 4,627 in 1813 - an increase of 93%, with the majority of that growth coming in the woodworking area which grew by 100% although the proportional increase in the metal area, which employed a much smaller number of men, was by far the largest at 356%.

Figure 8.2 brings together the trends across the whole period for the increase in the size of the fleet, the increase in Portsmouth's output and the rise in the Dockyard workforce and it can be seen that the general slopes of all three graphs are remarkably parallel. It also suggests that the year on year demand for increased output from the Yard continued up to 1812/1813. Equating the increase in output

FIGURE 8.2

% CHANGE RELATIVE TO 1790 (93 - FLEET)

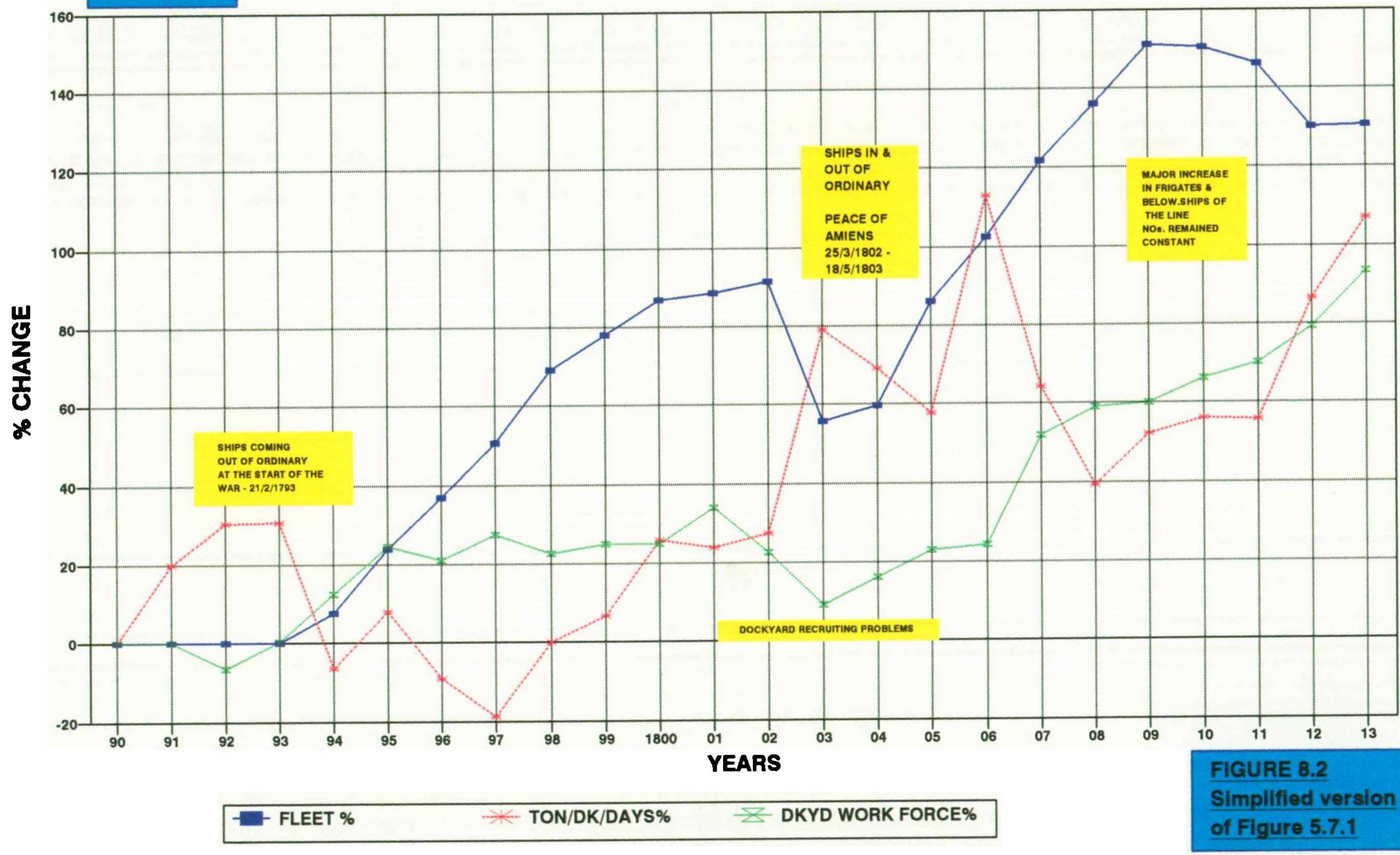


FIGURE 8.2
Simplified version of Figure 5.7.1

of 107% with the 93% increase in the workforce suggests that productivity increased by some 14% but this is almost certainly an under assessment since the output calculation, which derives solely from ships passing through Portsmouth, takes no account of articles produced at Portsmouth, such as copper sheeting and rigging blocks which were supplied to other Royal Dockyards and Naval Bases around the world. How much of this 14% increase can be directly attributed to the new technologies is impossible to determine but indisputably the gains in the metal/ wood mills were totally based on it.

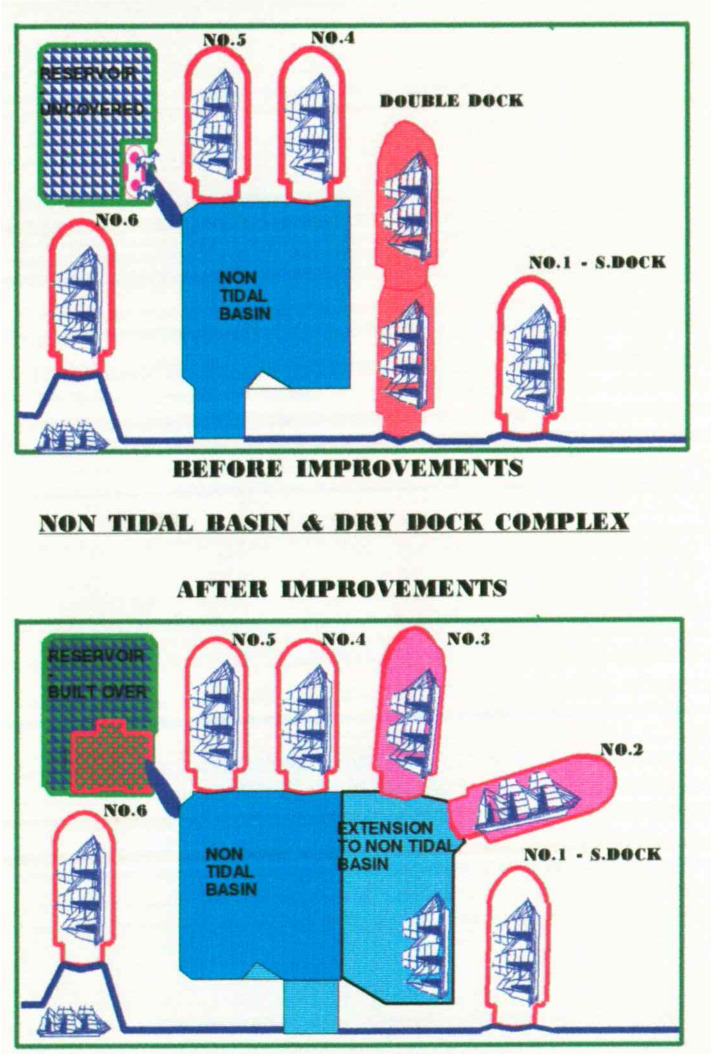
New technologies were examined firstly by looking to see when technical advances relevant to the work in Yard became available and secondly, when and why they were or were not introduced into the Dockyard. As has already been suggested there were few technical advances in this period that could be applied to work undertaken "in situ" on ships in dock or at alongside berths and therefore it was in the dockyard "factories" that new technologies were first applied. However, in this period Portsmouth had only three "shops" or installations that fell within this category; the smiths' shop, the joiners' shop and the ropeyard. The latter was the one major area into which Portsmouth did not introduce any new machinery and whilst there is no authoritative record to explain why this was so, a strong case can be made for suggesting that a series of fires in the ropeyard in 1760, 1770 and 1776 may have persuaded the authorities that it was better if Portsmouth looked to other sources for its increasing rope requirements. Indeed the total lack of any records on the subject suggests that the subject did not even generate sufficient interest to merit discussion. Similarly Portsmouth Dockyard, like all the others, continued the practice of purchasing its canvas, still hand woven in this period, from commercial sources.

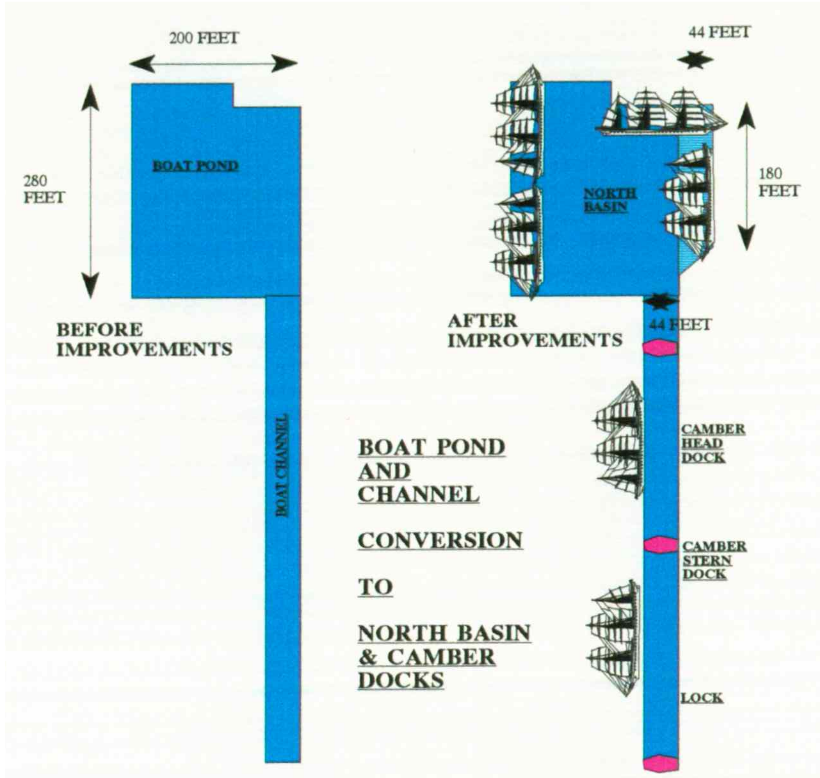
Although the Admiralty and Navy Boards' prime interest, as far as the Royal Dockyards were concerned, focused on the timely despatch of serviceable ships to the operational fleet, both bodies were constantly concerned about the assured supply (in both qualitative and quantitative terms) of vital materials and manufactured products. Furthermore these Boards were forever searching for economies in the face of the inescapable annual year on year increases in the costs in maintaining the growing and ageing Fleet.

In this thesis the investigation of new technology introduced into Portsmouth Dockyard has been carried out under the four headings of the Dry Docks, Metal, Fibre and Wood working. Unfortunately, due to the size constraints of the thesis, it was not possible to give as much space to the support services such as water, lighting and firefighting as had been originally intended. As has already been discussed there was in fact no new technical investment in the fibre area at Portsmouth but that was not true of Chatham where ropemaking machinery from this period is still in operation to this day. This, taken together with the investment in Portsmouth in the other areas, gives rise to the suspicion that there was an overall plan by the Navy Board to spread the introduction of technology across several dockyards. However no evidence to support this has been uncovered during the research into developments at Portsmouth and this was disappointing since the idea would have been eminently sensible and it certainly seems to fit the facts.

In 1795, at the time of the introduction of the Office of the Inspector General of Naval Works, Bentham's attention at Portsmouth focused initially on the dry dock complex for the introduction of new technology. In 1793 a contract had been raised, though not yet activated, to increase the overall capacity by enlarging the existing double dock, but Bentham appreciated that what was really needed was a substantial increase in "throughput" and the basis for achieving this would be to radically reduce the amount of time ships had to wait for the right tidal conditions before entering or leaving dry dock. Figure 7.3.1 showed the complex before and after Bentham introduced new civil engineering concepts to the Dock Entrances, steam power to the dock pumps, caissons to the dock entrances and subsequently the first steam powered dredger to clear and deepen the dock approaches. Equally imaginative was the incredibly cheap conversion and enlargement of the boat pond into the North Basin (non-tidal basin for fitting out frigates and other small vessels) and with an approach to it which could be used as a double dock, this was illustrated in Figure 7.3.3. In combination all these advances, shown in Figure 8.3 (a composite from Figures 7.3.1 and 7.3.3) enabled the Dockyard to dock about twice as many ships with 8 docks as they had done earlier with 5 docks. Capital installation costs were saved by using one steam plant for two different purposes as a result of placing the Wood Mills on top of the Reservoir and using it to drive the wood machinery by day and pump out the Reservoir by night. This innovation also allowed the steam engine to be operated more efficiently as a result of being kept in near continuous use.

In fact the first steam engine, a 12 hp. Sadler engine designed by the first (and only) Chemist in the Office of the Inspector General of Naval Works, did not arrive on site until 1799. However, by 1807, as was shown in Figure 7.2, there were seven engines in use in the dockyard with a combined horsepower of 146 hp. It would be easy to assume that once steam power was accepted, a "culture" would develop around it and the use of progressively more powerful steam engines would proliferate regardless of whether they represented "value for money". Indeed the Navy Board and the Portsmouth Dockyard Management appear to have kept their feet firmly on the ground and only invested in steam power, and indeed other new technology, when the economics of a particular installation made sense. Thus a number of possible uses of steam power were not taken up, for instance No.1 and No.6 docks continued to be pumped by horse teams. One should applaud this hard headed approach to a technical revolution since it would have made no sense to install steam engines which would have spent most of the time sitting cold and idle.





NEW BOAT POND EQUIVALENT TO 220" x 220" PROVIDED TO WEST BY RECLAMATION

AN AREA CIRCA 680" x 300" PROVIDED TO THE WEST BY RECLAMATION TO REPROVIDE SPACE FOR TIMBER STORAGE & SAW PITS LOST TO NEW TECHNOLOGY INSTALLATIONS

DRY DOCK FACILITIES - BEFORE AND AFTER IMPROVEMENTS **FIGURE 8.3**

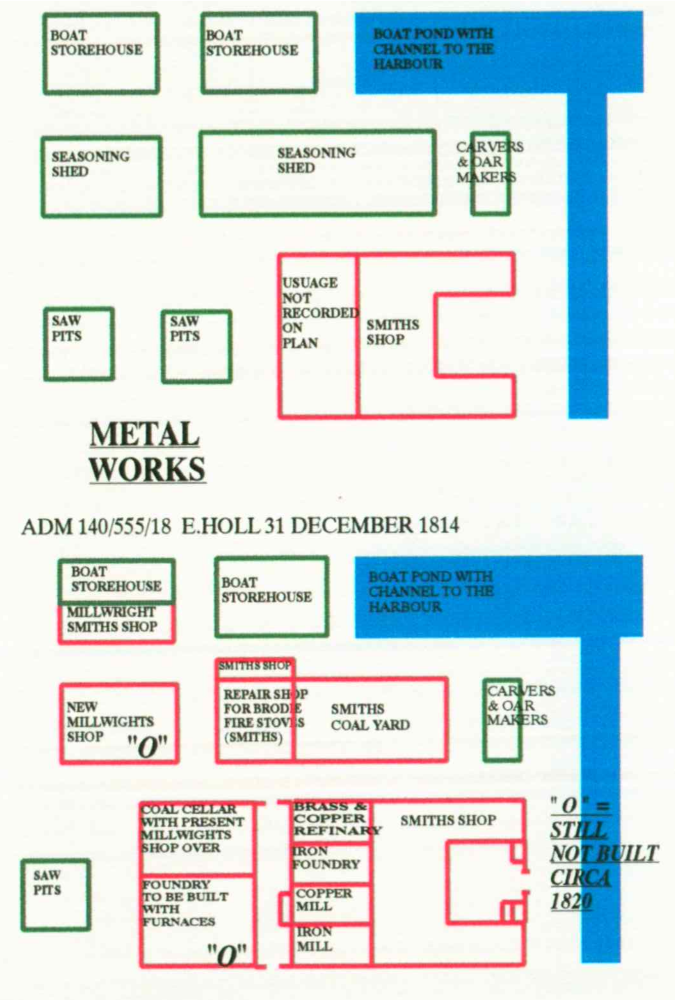
The investment in the Metal Mills also showed this strong attention to economics. In the first instance the proposal had been only to install furnaces to melt old copper sheeting down prior to transportation to commercial reprocessing facilities. Before this was implemented the scheme was expanded to include the actual re-processing itself both on the grounds of saving money and to ensure new sheeting met the Navy's standards. Furthermore, it is understandable that the Admiralty would always have felt that their commercial supplies, which came from Wales, were vulnerable to the storms of the Irish Sea as well as the deprivations of French privateers operating off Land's End. The Portsmouth Metal Mills solved all these problems and by 1807, after a number of installation difficulties, the Mills were providing no less than two thirds of the Navy's annual copper sheeting and bolt requirements from re-cycled material. Whilst no definitive "measures" (total acquisition/production costs adjusted for inflation to allow year on year comparison) of the cash savings have been discovered there can be little doubt that these were significant if for no other reason than there would have been considerable reductions in transportation costs. Today of course the 100% re-cyling of recovered copper and the resultant provision of around 66% of the total new copper requirement from it would be highly acclaimed in itself. Subsequently, as Figure 7.4.1 showed, the Metal Mills were the subject of further expansion into the brass and iron fields although, with the end of the war in 1815, not all the Dockyard management's aspirations were fulfilled.

As important as the immediate gains from the Metal Mills, and the other steam powered plants in the Yard, were the long term benefits which were to arise from these investments. In manpower terms these provided the basis for the development of the new metalworking crafts/trades such as millwrights, engine keepers and the rolling mill and foundry workers all of whom would prove fundamental to the Navy's and the Royal Dockyards' ability to build, maintain and repair the steam powered, iron hulled vessels which would enter the Fleet, in increasing numbers, in the second half of the nineteenth century.

Figure 8.4 summarises the totality of the factory developments at Portsmouth, with changes in the metal area on the left and wood/block mills on the right, and again it was the possibilities of financial savings and the protection of quality manufacturing standards that led to Bentham's advocacy of Brunel's designs for the block making machinery for the latter. This, unlike the Metal Mills development which essentially exploited established technology, broke new ground in the design and manufacture of the machines and in the wider concept of the development of production plants. By 1807, after a number of delays, the Mill was meeting the entire annual Naval requirement for blocks which in 1806 amounted to no fewer than 154,285 in a wide range of sizes - some of those machines

"FACTORY DEVELOPMENTS - THE METAL AND BLOCK/WOOD MILLS

ADM 140/555/15. E.TIPPETT 1 AUGUST 1793



BLOCK AND WOOD MILLS

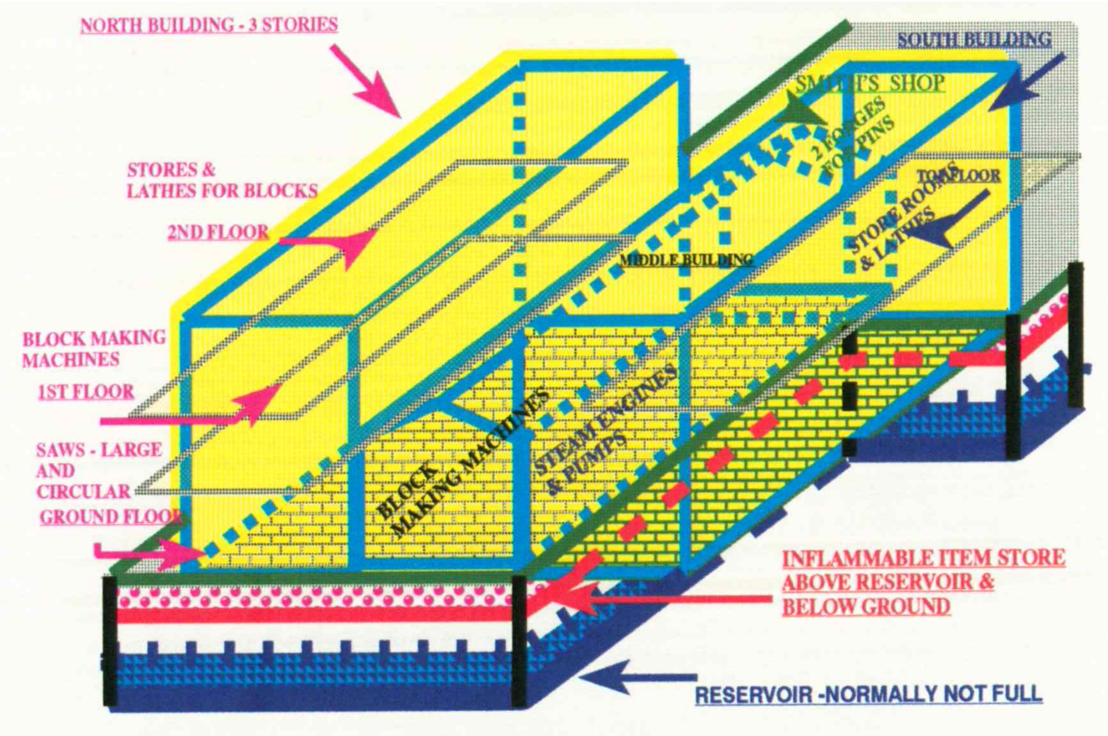
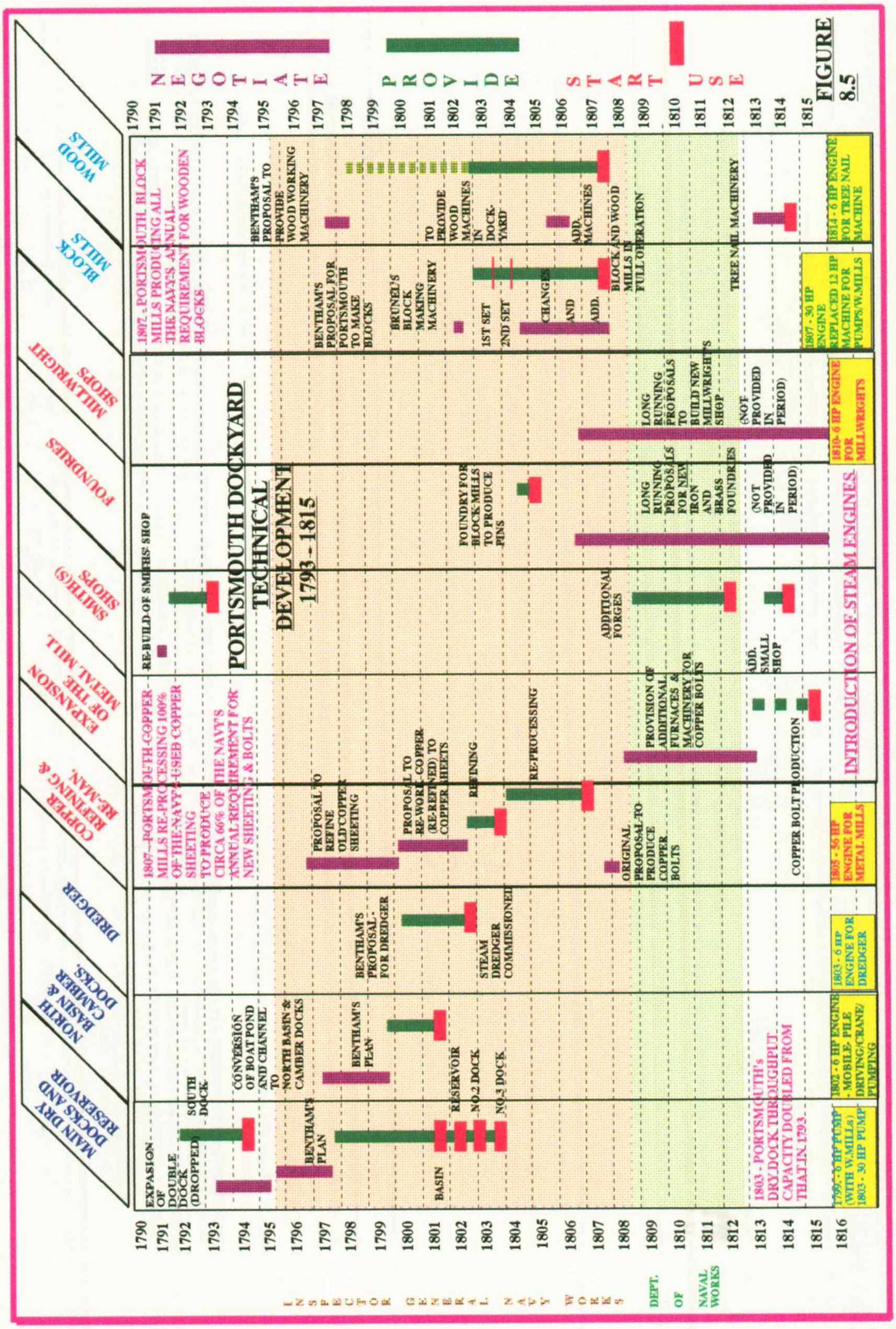


FIGURE 8.4

were still making blocks for the Navy over 150 years later. According to Brunel his block making plant employed one man for every ten employed by less advanced makers of blocks. If that was true the financial benefits for the Navy would have been considerable. Much more important, from the Fleet's point of view, would have been the consistency in block performance since simple though a block may appear, any significant additional clearances or, worse still, any inadequate clearances, would inevitably lead to a rope jamming with very serious possible consequences in bad weather. Again this technical evolution in Portsmouth had a significance beyond its own immediate application in that it established Marc Brunel, the father of the better known Isambard Kingdom Brunel, as an "inventor", an engineer and a project manager. Figure 7.5.1. provided a reminder that the Wood Mills were situated over the reservoir for the dry docks and embraced within them the steam plant which served both the mills and the reservoir and dock pumps. It also showed where the larger woodworking machines were situated and it may well be that it was the fact that the very large reciprocating saw; apparently capable of working on full size tree trunks, was placed in the centre of the yard mitigated against the introduction of further machines of this type in favour of the retention of traditional saw pits which were situated close to the raw timber stowages and the boundaries of the yard. Logic suggests that this arrangement would have presented a far easier movement problem than that involved with transporting the raw timbers to the Wood Mill and this supposition is reinforced by the fact that Brunel's woodworking equipment which was installed at Chatham from 1810 onwards was based around a very large and highly sophisticated hydraulic system for moving timber around the yard. Certainly the development of the use of hydraulics in the Royal Dockyards as a whole would seem to offer an interesting expansion of the work on the introduction of new technologies begun in this thesis.

Figure 8.5, which combines the salient features of Table 7.2 (Steam Engines) with Figure 7.6, shows that in less than twenty years major technical advances were introduced in Portsmouth in all areas except that of fibre work. It is true that there were a number of delays with both the metal and wood mills coming into production although in the case of the former much of this delay could reasonably be attributed to changes in requirements during the development of the projects. However the most impressive aspect of the total installation is that all three elements achieved, in full measure, the performance that they were designed for. Without question the Navy was extremely fortunate to have in Samuel Bentham, Marc Brunel, Simon Goodrich and a few others a highly competent team. These men had imagination, flair, drive and the technical competence to understand the potential of the technologies which were available, to devise means to apply them to the tasks in Portsmouth Dockyard, and in the relatively short space of time to bring them all into full and economic production. Undoubtedly it was the pressure generated by the demands of the war that persuaded the Admiralty


PORTSMOUTH DOCKYARD TECHNICAL DEVELOPMENT 1793 - 1815
MAIN DRY DOCKS AND RESERVOIR
NORTH BASIN & CAMBER DOCKS.
DREDGER
COPPER REFINING & RE-MAN.
EXPANSION OF THE METAL MILL
SMITH(S) SHOPS
FOUNDRIES
MILLWRIGHT SHOPS
BLOCK MILLS
WOOD MILLS
NEGOTIATE
PROVIDE
START USE
INSPECTOR GENERAL NAVY WORKS
DEPT. OF NAVAL WORKS
INTRODUCTION OF STEAM ENGINES
1803 - 6 HP ENGINE FOR DREDGER
1805 - 50 HP ENGINE FOR METAL MILLS
1810- 6 HP ENGINE FOR MILLWRIGHTS
1814 - 6 HP ENGINE FOR TREE NAIL MACHINE
FIGURE 8.5

Board to empower Bentham as it did in 1795. However, it was inevitable that when those pressures began to ease then the establishment would take its revenge on the "outsider" and as Figure 7.1.1 showed, his "power base" was first curtailed by the Navy Board in 1808 and then finally abolished in 1812. But by that time the age of steam and new machines was firmly established and indeed this was given official recognition in 1814 with the appointment of Simon Goodrich as the Navy's first Mechanist and Engineer, a post he held until 1831. With the exception of Ian Christie's book on Bentham's years in Russia, there is no twentieth century biography of Bentham, furthermore there is no biography of Simon Goodrich and both men would seem worthy of further study.

Many histories of the Royal Navy tend to portray the support organisations of the Navy, and the Royal Dockyards in particular, as incompetent, inefficient and frequently corrupt. Roger Morriss encapsulated this view when he wrote "Traditionally they have always been regarded as technologically backward compared with private industry, wasteful of public funds and ship-building resources and a check, from their inefficiency, on the efforts of the fighting navy". However the Royal Navy of the Napoleonic Wars could not have been kept at sea for over twenty years without an effective maintenance system for upwards of 900 ships, more than a third of whom were refitted in Portsmouth.

It follows that without the increase in Portsmouth Dockyard's output, the number of serviceable ships of the Fleet at sea would have been fewer. Consequently the flow of supplies to the Peninsular Army might well have been diminished, the inflow of vital raw materials for the Royal Navy and Industry would have been reduced and the outflow of manufactured goods to the markets around the world, on which depended the wealth of this country and the revenues which sustained the war against Napoleonic France, might also have been curtailed. In short, the strategic consequences of Portsmouth Dockyard not meeting the demands which where placed on it could have been serious for the Nation.

As this thesis has shown, the efficiency of that Yard undoubtedly increased significantly during the war even if it did not match the ideals of its critics who usually were able to ignore any financial constraints imposed on the Dockyard Management. Whilst the evidence of this thesis does not substantiate the suggestion that Portsmouth's achievements were only made possible by the new technologies, it does make the case with confidence, that the new technologies contributed significantly to the vital increase in dry dock throughput and that they were wholly responsible for the achievement of major economies in the metal and blockmaking processes. Moreover it can also be argued that the variety of new technologies introduced on the one site of Portsmouth Dockyard was unusual for the period - possibly even unique. Interestingly, this thesis also reveals a consistently innovative and financially responsible approach to the introduction of new technology in Portsmouth, which is very different from the impression that history generally accords the Royal Dockyards.

Finally, it has been shown that both the history of the Royal Navy and the history of Technology are enriched by the inclusion of the technical advances in Portsmouth Dockyard in the period 1790-1815.

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5.1	Display of Shipwrights' tools, The Historic Dockyard, Chatham.
5.1.1	Demonstration at the Weald and Downland Open Air Museum, Singleton.
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